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WETLANDS FUNCTIONS AND VALUES STUDY PLAN

by

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This report presents a research protocol for wetlands functions and values studies. An assessment technique developed for the Federal Highway Administration (FHWA) will serve as the framework for these activities.

The study plan describes a multiyear research effort that will lead to the refinement, regionalization, and computerization of the FHWA Technique.

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20. ABSTRACT (Continued).

The study plan also identifies research to strengthen the FHWA Technique by improving the technical literature upon which the technique is based.

The study plan balances Corps wetlands values assessment needs with weaknesses in the technical literature to produce a list of national research priorities. Priority research identified in the study plan includes hydrology, water quality, and fish and wildlife studies (primary and secondary productivity) in:

a. Bottomland hardwoods, including swamps, of the Gulf and South Atlantic Coasts and Interior: Midcentral Regions,
b. Freshwater marshes adjacent to rivers and lakes in the Interior: North Central-Great Lakes Region,
c. Estuarine marshes in the Pacific Coast Region,
d. Swamps in the North Atlantic Region, and
e. Tundra in the Alaska Region.

Pricrity function-specific studies and some special studies are also identified.

Due to the complexity of the research efforts and the large number of identified research priorities, the Wetlands Research Program will address only selected research studies. Other agencies and research institutions are encouraged to conduct priority studies identified in this study plan.

Socioeconomic studies were not included as priority research during implementation of the first 2 years of the research because basic understanding of many wetlands functions is currently limited. Socioeconomic studies will be initiated as understanding of specific wetlands functions increases.

PREFACE

This report was sponsored by the Office, Chief of Engineers (OCE), US Army, as a part of the Wetlands Research Program (WRP). The WRP is conducted by the Environmental Laboratory (EL), US Army Engineer Waterways Experiment Station (WES). OCE Technical Monitors for the WRP were Drs. J. Hall and R. J. Pierce and Mr. P. C. Pierce.

The report presents a comprehensive wetlands functions and values study plan. The study plan, which was developed according to a logical, stepwise approach, will be used as a guide to a multiyear research effort to develop methods for quantifying wetlands values. The study plan incorporates information obtained from an evaluation of existing wetlands assessment methods, a survey of Corps of Engineers (CE) wetlands values information needs, state-of-the-art literature reviews, and a CE wetlands values workshop. Research identified in the study plan is designed to strengthen a wetlands values assessment method recently developed for the Federal Highway Administration.

Authors of the report were Mr. E. J. Clairain, Jr., Dr. D. R. Sanders, Sr., Dr. H. K. Smith, and Mr. C. V. Klimas, all of the Wetlands and Terrestrial Habitat Group (WTHG), Environmental Resources Division (ERD), EL. The report was prepared under the general supervision of Drs. Sanders and Smith, WTHG; Dr. C. J. Kirby, Chief, ERD; and Dr. John Harrison, Chief, EL.

During the preparation of this report, COL Tilford C. Creel, CE, and COL Robert C. Lee, CE, were Commanders and Directors of WES and Mr. F. R. Brown was Technical Director. At the time of publication, COL Allen F. Grum, USA, was Director and Dr. Robert W. Whalin was Technical Director.

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CONTENTS

* Appendixes A-B are published separately.

CROSS-REFERENCE OF IDENTIFIED WETLAND TYPES AND THE NATIONAL WETLANDS INVENTORY (NWI) CLASSIFICATION SYSTEM

Name Used in Text	NWI Classification
Bogs	Palustrine Scrub/Shrub
Bottomland hardwoods	Palustrine Forested
Estuarine emergent	Estuarine Emergent
Estuarine marshes	Estuarine Emergent
Estuarine scrub/shrub	Estuarine Scrub/Shrub
Fens	Palustrine Emergent
Forested and unforested freshwater tidal	Palustrine Forested and Palustrine Emergent
Freshwater marshes	Palustrine Emergent
Lacustrine	Lacustrine
Lacustrine emergent	Lacustrine Emergent (Nonpersistent)
Lakes	Lacustrine
Mangrove swamps	Estuarine Scrub/Shrub
Marine	Marine
Mud flats	Unconsolidated Shore/Bottom
Palustrine	Palustrine
Palustrine aquatic bed	Palustrine Aquatic Bed
Palustrine emergent	Palustrine Emergent (Persistent)
Palustrine forested	Palustrine Forested
Palustrine moss/lichen	Palustrine Moss/Lichen
Palustrine scrub/shrub	Palustrine Scrub/Shrub
Playa lakes	Lacustrine/Palustrine Emergent
Pocosins	Palustrine Scrub/Shrub
Prairie potholes	Palustrine Emergent (Persistent)
Reservoirs	Lacustrine
Riparian forests	Palustrine Forested
Riverine	Riverine
Riverine emergent	Riverine Emergent (Nonpersistent)
Salt marshes	Estuarine Emergent
Seagrass beds	Marine Aquatic Bed
Shrub carrs	Palustrine Scrub/Shrub
Swamps	Palustrine Forested
Tundra	Palustrine Emergent
Vernal pools	Palustrine Emergent
Wet meadows	Palustrine Emergent
Wet tundra	Palustrine Emergent

WETLANDS FUNCTIONS AND VALUES STUDY PLAN

PART I: INTRODUCTION

1. Wetlands have many valuable functions, including fish and wildlife habitat, flood storage and desynchronization, ground-water recharge/discharge, nutrient and heavy metal immobilization, sediment retention, shoreline anchoring, silviculture, and aesthetics. Not all wetlands provide the same functions, and the importance of functions differs both within and among wetland types. Some wetlands have well-documented and critical functions; others have poorly understood or less important functions.

2. The Corps of Engineers (CE) has recognized the need for a technique that can be used to reliably assess and quantify wetlands values. Responsibility for developing an assessment technique has been assigned to the US Army Engineer Waterways Experiment Station (WES).

3. No single assessment procedure currently available affords the capability for accurately quantifying all functions attributed to wetlands; however, a procedure developed for the Federal Highway Administration (referred to as the FHWA Technique) provides an excellent framework for assessment.

4. The FHWA Technique (Adamus 1983) has been tentatively adopted as the basis for a CE wetlands functions and values assessment procedure. The greatest attribute of this technique is that it is based entirely on the technical literature; thus, it has the potential for providing the best technical assessment. Unfortunately, the literature is weak in many areas.

5. The objectives of this study plan are to:

   a. Present a logical framework for developing a wetlands assessment technique.

   b. Propose steps necessary to improve the procedural organization of the FHWA Technique.

   c. Identify regional and national priorities for research to strengthen the technical validity of the FHWA Technique.

   d. Present methods for effective information transfer.

The study plan balances CE wetlands information needs with weaknesses in the technical literature to produce a list of national research priorities. This list is intended to guide future wetlands evaluation research; however, the scope of the plan is so broad that only items of highest CE priorities will be

implemented. This plan should also assist others (e.g. Federal agencies and academia) in identifying productive research areas.

6. The study plan is divided into seven parts. Part I presents the objectives and other introductory information. Part II presents the approach for development of this study plan. Part III provides regional research priorities and the rationale for identifying these priorities. Part IV identifies national research priorities. Part V discusses the FHWA Technique and proposed revisions. Part VI presents mechanisms proposed to ensure effective information transfer to CE Districts, other Federal agencies, and the general public. Part VII describes a framework for project implementation.

PART II: APPROACH

7. The general approach to developing this study plan was to select an assessment procedure that could serve as the basic framework for developing a useful technique, modify the organizational structure of the selected technique as necessary, identify research that could be used to strengthen and refine the technical validity of the selected technique, and develop effective information transfer methods. Coordination with other agencies having similar interests and needs has been sought throughout development of this approach to ensure broadest acceptance and application of the results. A series of interrelated steps were identified to address the approach. These steps are illustrated in Figure 1 and described below.

Step 1. Assessment of Existing Wetlands Evaluation Techniques

8. Forty wetlands evaluation techniques published prior to 1981 were assessed to determine their advantages and disadvantages (Appendix A; Lonard et al. 1984). No single technique was found to provide an adequate framework upon which to develop a method responsive to CE needs. Therefore, a survey of CE Districts was conducted to determine whether they used unpublished techniques for wetlands evaluation.

Step 2. CE Survey of Wetlands Values Information Needs

9. Thirty-seven CE Districts were surveyed to determine currently used assessment techniques, wetland types receiving greatest developmental pressures, research priorities, and user needs. Survey details are provided in Appendix B (Forsythe, Clairain, and Smith 1983).

10. The survey indicated that Districts do not use formal wetlands assessment methods; instead, they rely primarily on professional judgment. Wetland types receiving most intense developmental pressures nationally were: bottomland hardwoods,* freshwater marshes, swamps, and estuarine marshes.

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* A cross-reference listing of common names for wetland types and National Wetlands Inventory terminology appears on page 4.

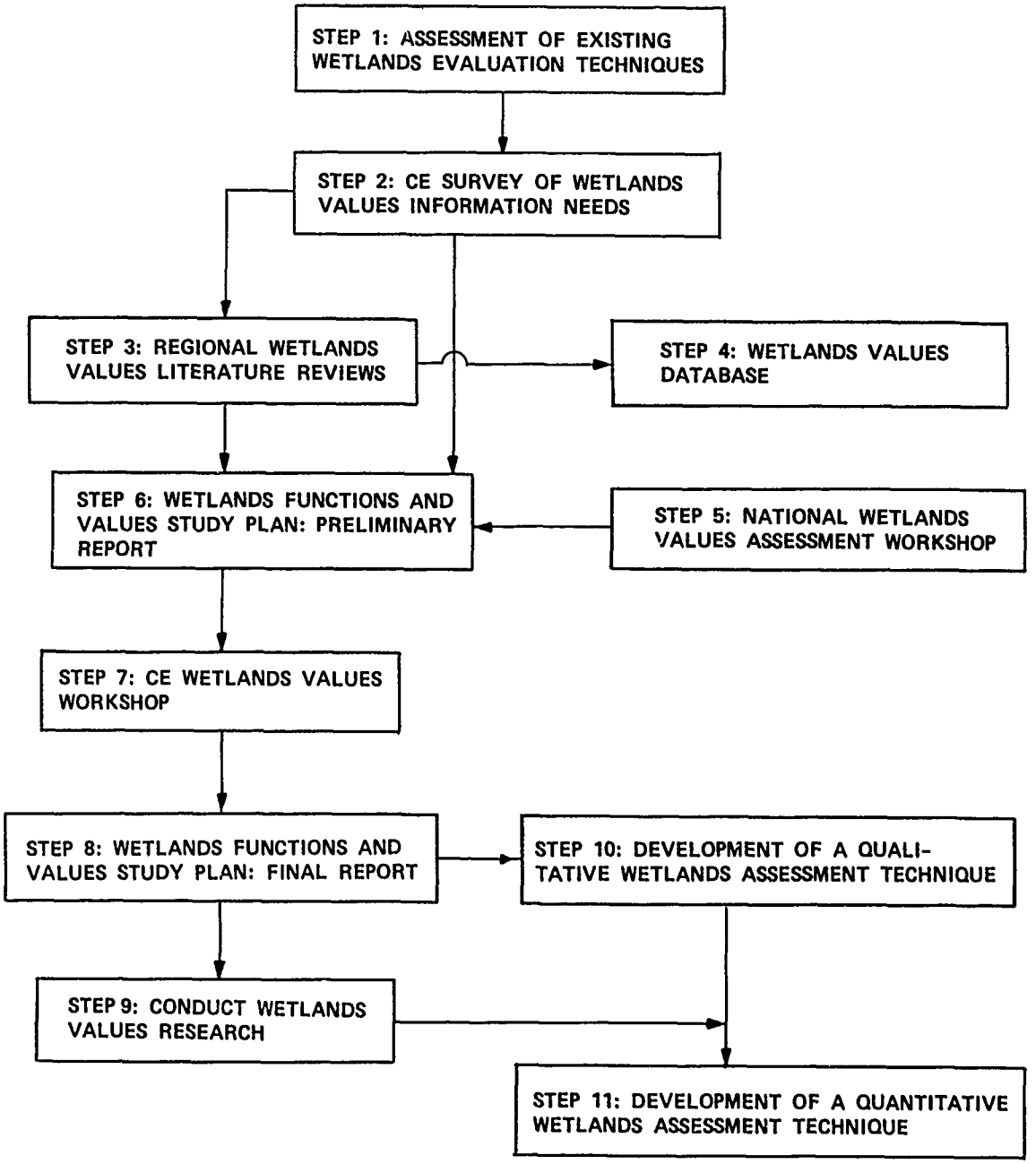


Figure 1. Steps in development of wetlands functions and values research

Highest national research priorities were: food chain production, heavy metal immobilization, nutrient uptake, ground-water recharge/discharge, flood storage and desynchronization, reduction of suspended solids, aquatic habitat, and erosion abatement. Characteristics identified by CE Districts as desirable of a wetlands evaluation technique were: flexibility, scientific validity, regional applicability, and acceptability by the CE and other agencies. The need for regionalized summaries of wetlands values information, together with a mechanism for rapid retrieval, was also identified.

Step 3. Regional Wetlands Values Literature Reviews

11. A thorough review and synthesis was conducted of existing wetlands functions and values literature. Literature on wetlands functions was regionalized (Figure 2) and reported by four broad categories: hydrology (Jones and Klimas 1985), water quality (Nixon and Lee 1985), fish and wildlife (Bane, Bane, and Ellsworth 1985), and socioeconomics (Shabman and Batie 1985). Each literature review examined the quantity and quality of available information, and this information was synthesized by wetland type and specific function or value for each region. The socioeconomic literature review was not regionalized due to limited region-specific information. The reviews also provided recommendations for additional research to address identified data gaps.

Step 4. Wetlands Values Database

12. To provide a mechanism for rapid retrieval of published wetlands values information as requested in the survey, the CE and the US Fish and Wildlife Service (FWS) are jointly developing a computerized literature retrieval system that can select articles by various categories, including location, wetland type, CE District or Division, wetlands function or value, and author, and provide a complete citation and abstract of each article. The database, which presently contains about 3,500 articles, is being expanded toward a goal of more than 6,000 articles. Selected CE Districts are assessing the user-friendliness of the system and will provide recommendations for revisions. The system will ultimately be made available to all CE Districts.

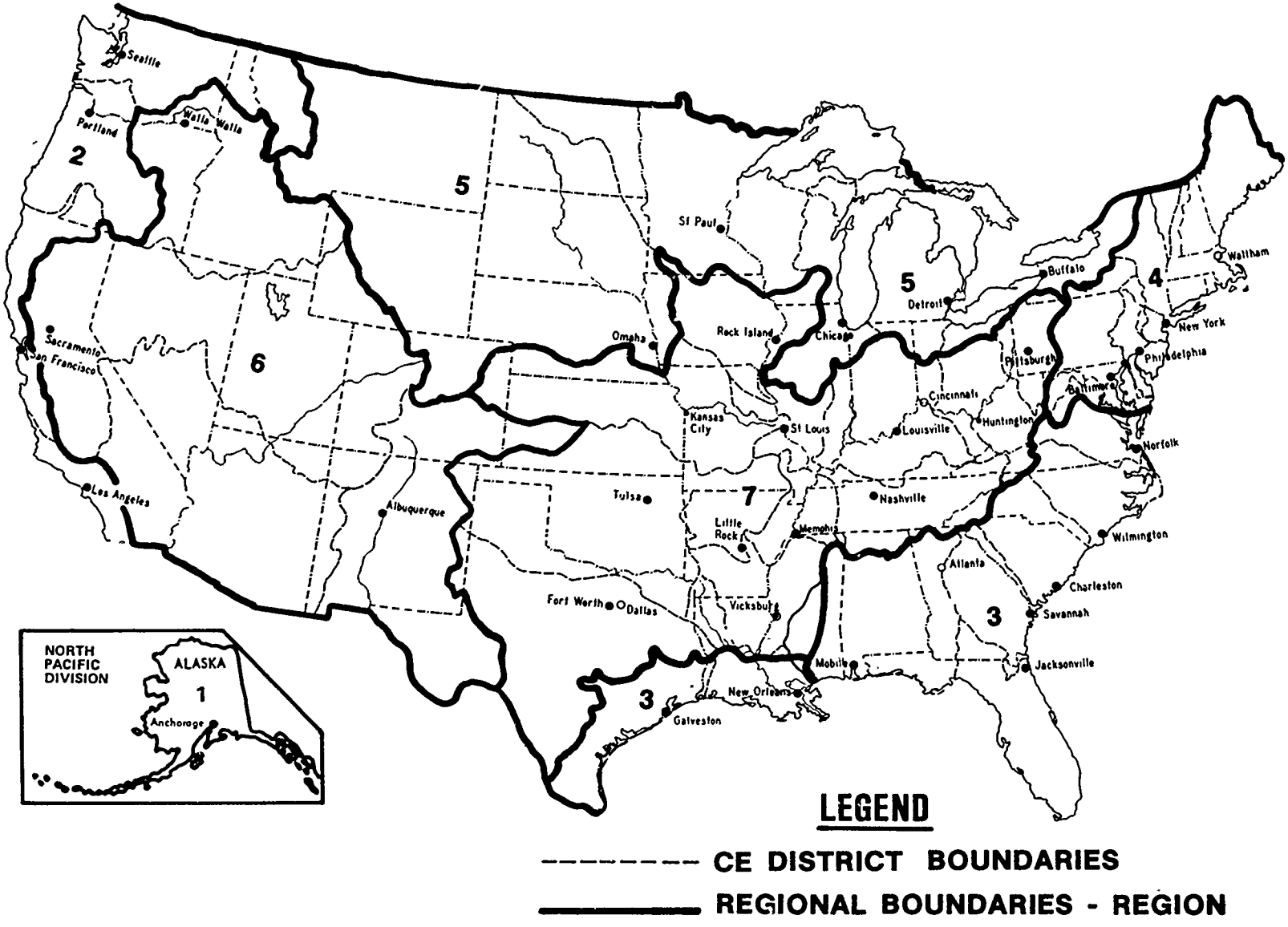


Figure 2. Map of the seven research regions

Step 5. National Wetlands Values Assessment Workshop

13. After reviewing the available assessment techniques, a procedure developed by the Federal Highway Administration was recognized by the CE and other Federal and State agencies as having potential merit. A workshop hosted by the FWS and cosponsored by 17 agencies was held in 1983 to critically review the FHWA Technique and provide recommendations for revisions and needed research. The technique was thoroughly examined by panels of experts on wetlands hydrology, food chain production, water quality, fish and wildlife habitat, socioeconomics, and wetlands assessment methodologies (Sather and Stuber 1984).

Step 6. Wetlands Functions and Values Study Plan: Preliminary Report

14. This document identified regional research needs by integrating information derived from Steps 1-5 and other information sources, including distribution of CE permitting activities and national or regional symposia and workshops. Research needs were presented for all regions, regardless of potential overlap between regions or wetland types or potential funding requirements, in an effort to provide the broadest research scope.

Step 7: CE Wetlands Values Workshop

15. The preliminary study plan was reviewed at a CE workshop held in 1983. The following questions were addressed: "Are regional research priorities identified by WES an accurate indication of research needs? If not, what should be the regional research priorities, and why?" The workshop was attended by 41 CE elements and several other Federal agencies. Workshop participants were divided into small regional working panels to provide an effective atmosphere for expression of ideas. The workshop panels developed specific recommendations for regional research needs. Regional research needs were used to establish national research priorities.

Step 8. Wetlands Functions and Values Study Plan: Final Report

16. Steps 1-7 provided background information for development of this document. The final study plan presents recommendations for development of a technically sound wetland assessment technique. A national research approach is also provided to address priority needs. Recommended research is discussed in Part IV. Results will be used to strengthen and refine the FHWA Technique.

Step 9. Wetlands Functions and Values Research

17. Selected high-priority research identified in the final study plan will be initiated by WES in fiscal year (FY) 1985. The number and breadth of studies will be dependent upon available funds and other constraints.

Step 10: Development of a Qualitative Wetlands Assessment Technique

18. The FHWA Technique has been adopted as the framework for development of a method for CE use. Revision of this qualitative technique will be initiated in FY 1984, and a revised version will be available in FY 1985. Emphasis will be placed on incorporation of recent literature and structural modifications, and development of computer software. After field testing, the technique will be further revised to include "red-flag" features, regional considerations, computer enhancements, and a sensitivity analysis.

Step 11: Development of a Quantitative Wetlands Assessment Technique

19. As results of research from Step 9 become available, function-specific information will be incorporated into the revised FHWA Technique developed in Step 10 to strengthen its technical validity. Function-specific quantitative methods resulting from research efforts will also be incorporated as they become available.

PART III: REGIONAL RESEARCH PRIORITIES

20. Research needs were identified to establish regional research priorities. The continental United States was divided into seven regions based on wetland types, geography, and CE District boundaries (Figure 2). Research needs and developmental pressures were obtained from the CE survey and were refined by the CE workshop. Literature reviews were regionalized, and the quantity and quality of information were assessed by function and wetland type to identify data gaps. The literature reviews are not presumed to be all-inclusive, but reflect the relative distribution of information available by topic. Generally, research priorities were established by a synthesis of research needs determined from the survey, literature reviews, and the CE workshop.

Region 1 - Alaska

District survey

21. Wetlands developmental pressures. Greatest developmental pressures occurred in the following wetland types: tundra (30 percent), bogs (23 percent), estuarine marshes (17 percent), and lacustrine (12 percent), (Figure 3).

22. Research needs. Functions assigned highest research priority were: water supply; aquatic habitat; flood (water) storage and desynchronization; food chain production; waterfowl habitat; ground-water recharge/discharge; terrestrial habitat; and erosion abatement (Figure 4).

Literature reviews

23. Hydrology. Sediment retention and shoreline anchoring have been studied fairly intensively. Water budget components, ground-water recharge/discharge, flood storage and desynchronization, and water supplies have not been well defined in the region. Marine, estuarine, and riverine systems have received the most research attention, while hydrologic functions in lacustrine and palustrine wetlands remain relatively unknown (Table 1).

24. Water quality. Research has been restricted almost entirely to tundra (Table 2). The reviewer described knowledge of the effects of Alaskan wetlands on water quality as "primitive." The only mass balance study, which

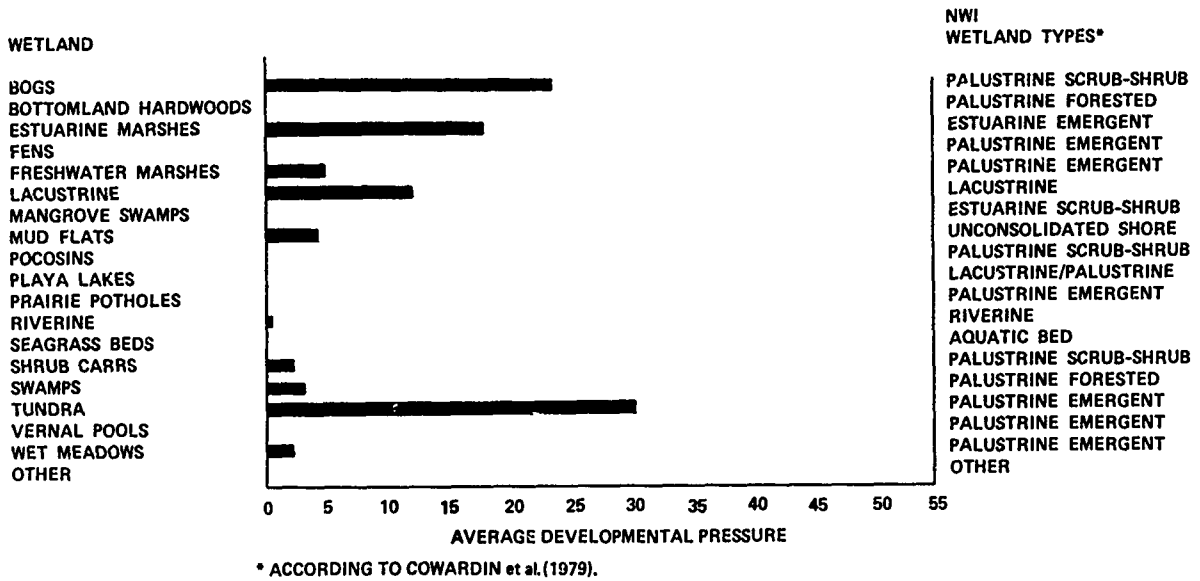


Figure 3. Average developmental pressure on wetland types, Region 1 - Alaska

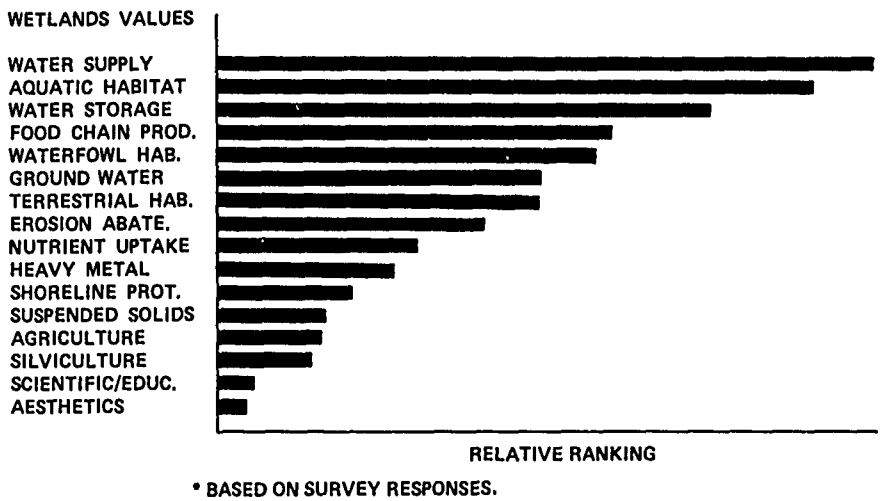


Figure 4. Relative ranking of wetlands research priorities, Region 1 - Alaska

Table 1

Number of Citations* of Wetlands Hydrologic Functions in Region 1

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception			1				1
Evapotranspiration		1	3	2	2	6	14
Ground-water recharge			5	4	6	11	26
Ground-water discharge			7	3	4	8	22
Sediment retention	17	14	9	6	2	6	54
Flood storage and desynchronization			8	3	4	6	21
Shoreline anchoring	23	15	5	3		1	47
Water supply	1	1	5	1	2	8	18
General			1	1	1	12	15
Total	41	31	44	23	21	58	218

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 2

Number of Citations* of Wetlands Water Quality Functions in Region 1

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen										1	1
Phosphorus											
Metals											
Sources											
N-fixation										1	1
Mobilization from sediment										1	1
Nitrogen										4	4
Phosphorus										5	5
Metals											
Export											
Nitrogen											
Phosphorus											
Metals											
Sinks											
Denitrification										1	1
Burial											
Nitrogen										3	3
Phosphorus										3	3
Metals										1	1
Uptake											
Nitrogen										7	7
Phosphorus										7	7
Metals											
Transformers											
Nitrogen										2	2
Phosphorus										1	1
Metals											
Total										37	37

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.
** According to Cowardin et al. (1979).

concerned nitrogen in wet tundra, revealed that much of the soil nitrogen is unavailable to plants and is not likely to be exported. The role of tundra as a source of nutrients and metals is not well studied, but export is thought to be minimal. Only one study of nitrogen fixation was found, and limited research has been conducted on leaching and litter loss. Little is known about chemical transformations in tundra, but this function appears to occur on a limited scale.

25. Fish and wildlife habitat. Despite the importance of Alaskan wetlands to fish and wildlife, relatively few publications were found. Most wildlife literature examined marine and estuarine systems (Table 3). Few studies focused on utilization of wetlands by salmonids. Productivity studies represent a major void.

CE workshop

26. Although Alaska District (CE) representatives did not produce a separate workshop report, they recommended that research be initiated in Alaska's unique permafrost areas to clarify hydrologic relationships, including water supply, flood storage and desynchronization, ground-water recharge/discharge, and erosion abatement.

Permit load

27. A total of 610 permit applications (4 percent of the national total) were received in 1982.

Research priorities

28. Hydrology. Research is needed to clarify hydrologic functions in tundra.

29. Water quality. Research is needed to assess the role of tundra as a:

a. Nutrient source, with emphasis on nitrogen fixation.

b. Nutrient sink, particularly in regard to nutrient uptake.

c. Transformer of nutrients and metals.

30. Fish and wildlife habitat. Research is needed to assess the role of:

a. Tundra and bogs as habitat for selected migratory waterfowl.

b. Estuarine wetlands as spawning and nursery habitat for selected aquatic species.

c. Estuarine and palustrine wetlands for food chain production.

Table 3

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 1

Wetlands Function	Wetland Type**					Total
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	
Wildlife habitat						
Mammals	20	2	2	1	1	26
Game	1		1	1	1	4
Nongame			1	1	1	3
Marine	6	1				7
Endangered						
Birds	37	13	5	5	9	69
Water birds	19	5		1	2	27
Raptors						
Passerines						
Game birds						
Reptiles/amphibians					1	1
Waterfowl habitat						
Aquatic habitat	3	3	1	1	1	9
Fish	4	7	11	4		26
Crustaceans/molluscs	2	1				3
Productivity						
Energy		1				1
Primary productivity	2	2				4
Secondary productivity						
Detritus						
General	5	3	8	3	2	21
Total	99	38	29	17	18	201

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

31. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, these rankings do not imply that socioeconomic functions are of little importance. Instead, they are not considered to be immediate District needs. Therefore, only limited studies on socioeconomic wetlands functions will be conducted during initial years of wetlands values research.

Region 2 - Pacific Coast

District survey

32. Wetlands developmental pressures. Developmental pressures were greatest in estuarine marshes (38 percent) and freshwater marshes (21 percent) (Figure 5).

33. Research needs. Functions assigned highest research priority were, in descending order: food chain production; ground-water recharge/discharge; reduction of suspended solids; terrestrial habitat; heavy metal immobilization; nutrient uptake; flood storage and desynchronization; and aquatic habitat (Figure 6).

Literature reviews

34. Hydrology. Very little information was found on wetlands hydrology (Table 4). Available literature largely dealt with erosional processes, sediment deposition, and flood storage and desynchronization. Sediment movement in large estuaries has received the most attention. The influence of wetland vegetation on shoreline erosion in riverine systems has been studied in some detail in the Pacific Northwest, but little information is available for California. Wetland influences on other hydrologic processes (e.g. ground-water recharge/discharge and evapotranspiration) have received almost no region-specific attention. The question of overall water supplies has not been evaluated in the context of wetlands functions (Table 4).

35. Water quality. Little information has been published on the effects of wetlands on water quality (Table 5). Nearly all identified research has been conducted in estuarine emergent wetlands, and no water quality studies were found for palustrine wetlands. No studies were found that documented complete mass balances for nutrients or metals in either estuarine or freshwater wetlands, and only one nitrogen fixation study was identified. Very

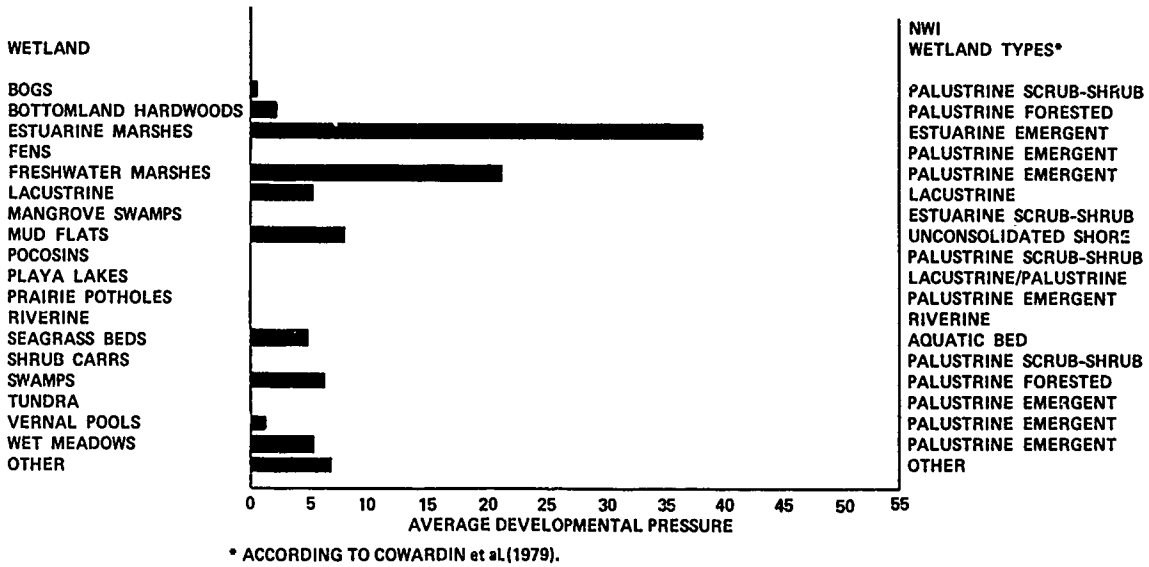


Figure 5. Average developmental pressure on wetland types, Region 2 - Pacific Coast

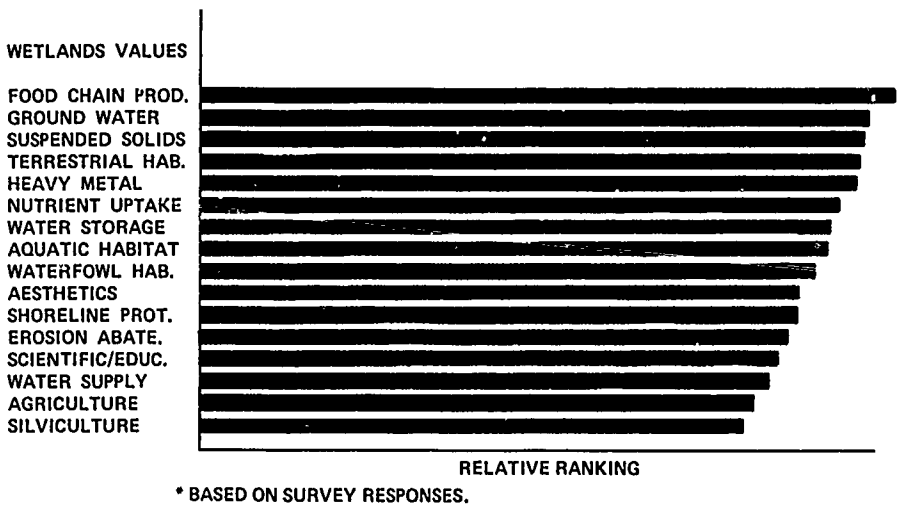


Figure 6. Relative ranking of wetlands research priorities, Region 2 - Pacific Coast

Table 4

Number of Citations* of Wetlands Hydrologic Functions in Region 2

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception							
Evapotranspiration					1		1
Ground-water recharge	1	2		2	1		6
Ground-water discharge							
Sediment retention	2	10	3	1		1	17
Flood storage and desynchronization	1	1	2	2	3	1	10
Shoreline anchoring	2	6		1			9
Water supply		1	1				2
General		2	1	1	1	4	9
TOTAL	6	22	7	7	6	6	54

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 5

Number of Citations* of Wetlands Water Quality Functions in Region 2

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen											
Phosphorus											
Metals											
Sources											
N-fixation			1								1
Mobilization from sediment											
Nitrogen			1								1
Phosphorus			1								1
Metals			6	2							8
Exports											
Nitrogen											
Phosphorus											
Metals											
Sinks											
Denitrification											
Burial											
Nitrogen			1								1
Phosphorus			1								1
Metals			1								1
Uptake											
Nitrogen			6	1							7
Phosphorus				1							1
Metals											
Transformers											
Nitrogen											
Phosphorus											
Metals											
Total			18	4							22

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

little work was found on nutrient content of emergent vegetation, but several studies addressed the role of emergent vegetation as a possible source of nutrients and metals to adjacent waters. Very few studies examined biomagnification of metals and nutrients in wetlands.

36. No measurements of denitrification were found, nor do available data provide sufficient information to estimate burial rates for nutrients or metals in either estuarine or freshwater wetlands. Studies of nutrient removal from sewage discharge indicated that some California wetlands retained a portion of additional nitrogen and phosphorus loading, thus acting as sinks during periods of elevated loadings. Transformation of different forms of nutrients and heavy metals by wetlands has not been described in sufficient detail to permit assessment of the effectiveness of wetlands to perform this function.

37. Fish and wildlife habitat. Fish and wildlife values have been well studied (Table 6), particularly in marine and estuarine wetlands. Fewer studies have been conducted in lacustrine and palustrine systems. This region ranked second among the seven regions in total number of region-specific wildlife references. The quality of syntheses and ecological characterizations for this region also appeared to be superior to those for other regions.

38. Considerable information was available for all wildlife groups, particularly birds and mammals, in marine and estuarine wetlands. All states in this region have active endangered species programs that have generated much useful wildlife data. Most riverine wildlife studies have been conducted along the Columbia and Snake rivers. The limited acreage of lacustrine wetlands is reflected in the scarcity of wildlife literature for this system.

39. Utilization of marine, estuarine, and riverine wetlands by fish species is generally well documented, particularly for salmonids. Data are lacking on the use of small mountain streams as fish spawning and nursery habitat. Lacustrine wetlands do not comprise a large portion of Region 2 wetlands, and studies on utilization of these systems by fishes are limited.

40. Information on aquatic ecology in palustrine systems is scarce. Wetlands productivity values have received very little attention. A few studies have described productivity in California estuarine marshes. Nothing was found on primary productivity, detrital production, or energy flow in riverine, lacustrine, or palustrine wetlands.

Table 6

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 2

Wetlands Function	Wetland Type**					
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	Total
Wildlife habitat						
Mammals	65	31	6	4	7	113
Game	11	8	6	3	6	34
Nongame		1	1		1	3
Marine	18	4				22
Endangered	1	1				2
Birds	104	75	11	13	22	225
Water birds	33	30	2	3	4	72
Raptors		1	1	1		3
Passerines						
Game birds	1	2			2	5
Reptiles/amphibians	1	2	3	1	3	10
Waterfowl habitat	9	14	3	2	6	34
Aquatic habitat						
Fish	79	24	37	9	3	152
Crustaceans/molluscs	15	7	1			23
Productivity						
Energy	1	1				2
Primary productivity	1	10				11
Secondary productivity	4	3	3			10
Detritus	1					1
General	172	164	32	10	19	397
Total	516	378	106	46	73	1,119

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

CE workshop

41. The workshop panel report recommended research on altered (e.g. diked) wetlands to determine the degree to which their functional integrity is retained. The report also recommended an analysis (not review) of existing fish and wildlife literature to identify areas needing research.

Permit load

42. A total of 1,351 permit applications (8 percent of the national total) were received in 1982.

Research priorities

43. Hydrology. Research is needed to assess the role of:

a. Riparian forests (palustrine forested) in flood storage and desynchronization.

b. Freshwater marshes in ground-water recharge/discharge.

c. Freshwater marshes in flood storage and desynchronization.

d. Altered wetlands in performing all hydrologic functions.

44. Water quality. Research is needed to assess the role of:

a. Estuarine marshes in heavy metal immobilization and nutrient uptake.

b. Freshwater marshes in removal of suspended solids.

c. Freshwater marshes in heavy metal immobilization and nutrient uptake.

d. Riparian forests in removal of suspended solids.

e. Altered wetlands in performing all water quality functions.

45. Fish and wildlife habitat. Research is needed to assess the role of:

a. Estuarine marshes in food chain production.

b. Freshwater marshes in food chain production.

c. Freshwater marshes as wildlife habitat.

d. Freshwater marshes as aquatic habitat.

e. Altered wetlands in performing all fish and wildlife functions.

46. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, these rankings do not imply that socioeconomic functions are of little importance; instead, these functions are not considered to be immediate regional needs. Therefore, only limited studies on socioeconomic wetlands functions will be conducted during the initial years of wetlands values research, possibly concentrating on the feasibility of using monetary analyses.

Region 3 - Gulf and South Atlantic Coasts

District survey

47. Wetlands developmental pressures. Thirty-eight percent of the developmental pressures occurred in estuarine marshes, 22 percent in bottomland hardwoods, 13 percent in swamps, and 9 percent in freshwater marshes (Figure 7).

48. Research needs. Functions assigned highest research priority were, in descending order: food chain production, nutrient uptake, heavy metal immobilization, aquatic habitat, flood storage and desynchronization, ground-water recharge/discharge, terrestrial habitat, and shoreline protection (Figure 8).

Literature reviews

49. Hydrology. Wetlands hydrology in the Gulf and South Atlantic States has been relatively well studied, particularly sediment retention and flood storage and desynchronization in estuarine and palustrine systems (Table 7). Ground-water recharge/discharge in palustrine systems has also been well studied.

50. Water quality. More information has been developed on the effects of wetlands on water quality in this region than in any other. Much of the research has been conducted in estuarine emergent wetlands, but considerable literature is also available on palustrine wetlands, particularly forested systems (Table 8).

51. Annual mass balance studies for nitrogen, phosphorus, and heavy metals have demonstrated that estuarine emergent and palustrine forests serve as sinks for nutrients and heavy metals. However, estimates of denitrification and nitrogen fixation usually were not included. Determination of mass balance in palustrine forested wetlands is difficult due to the lack of adequate hydrologic data to quantify water flow.

52. Nitrogen fixation has been recorded for 16 sites, and results suggest considerable nitrogen contribution from this process. The most extensive work on nitrogen fixation was conducted in salt marshes in Georgia and Louisiana. Concentration of heavy metals by plants has been well studied in estuarine wetlands. However, the available data fail to connect sources of

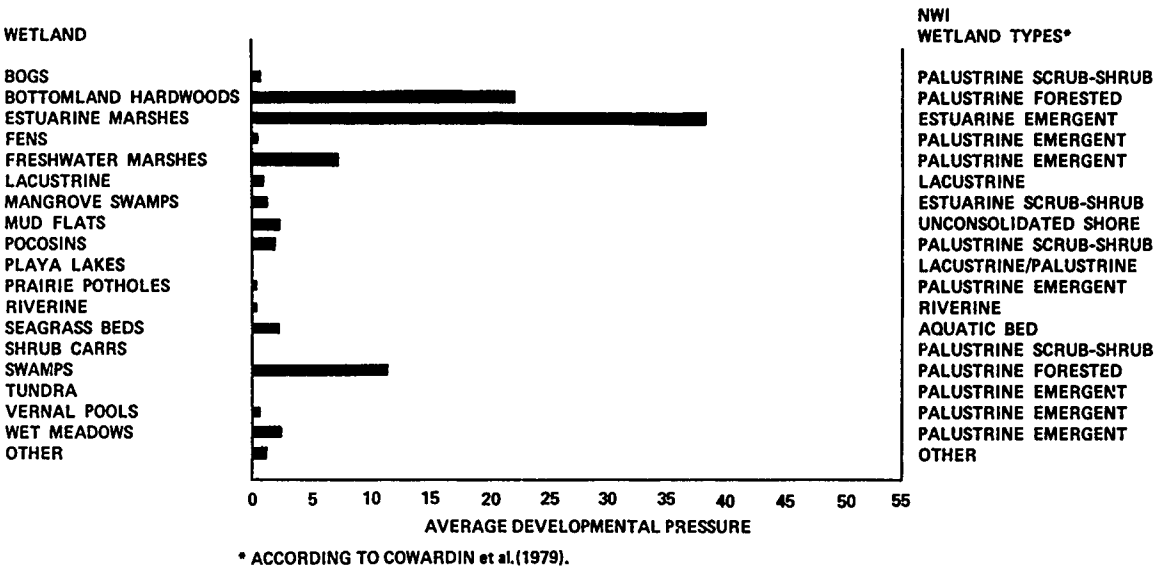


Figure 7. Average developmental pressure on wetland types, Region 3 - Gulf and South Atlantic Coasts

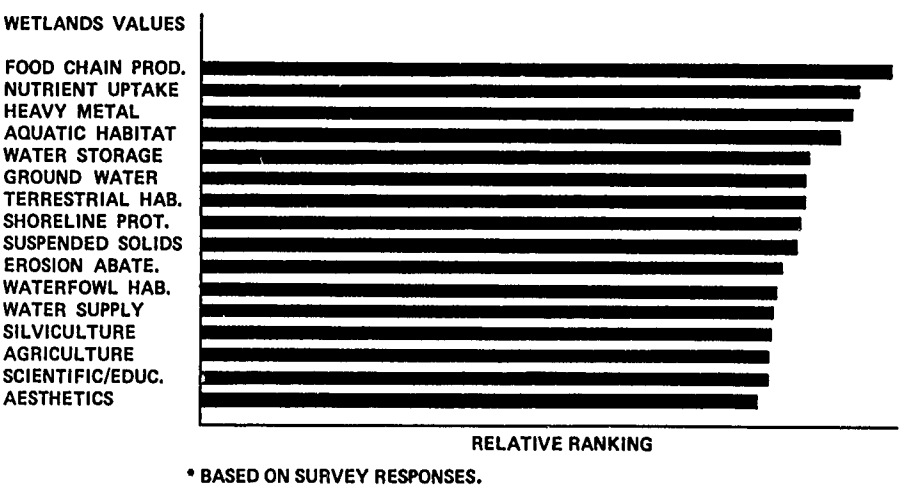


Figure 8. Relative ranking of wetlands research priorities, Region 3 - Gulf and South Atlantic Coasts

Table 7

Number of Citations* of Wetlands Hydrologic Functions in Region 3

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception					2		2
Evapotranspiration		4	1	4	4	8	21
Ground-water recharge	1	2	3	2	13	4	25
Ground-water discharge		2	3		9	2	16
Sediment retention	6	28	9		10	8	61
Flood storage and desynchronization	3	14	13		24	2	56
Shoreline anchoring	2	7	2	1	7	2	21
Water supply		1	2		2		5
General	2	7			1	13	23
Total	14	65	33	7	72	39	230

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 8

Number of Citations* of Wetlands Water Quality Functions in Region 3

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen			5			6					11
Phosphorus			4			7				3	14
Metals			6			1					7
Sources											
N-fixation		4	8			1					13
Mobilization from sediment											
Nitrogen			2			1					3
Phosphorus			2			1					3
Metals			3			1					4
Exports											
Nitrogen			6				1				7
Phosphorus			4				1				5
Metals			5								5
Sinks											
Denitrification			13			3				1	17
Burial											
Nitrogen			5			2					7
Phosphorus			4			1				1	6
Metals		1	8								9
Uptake											
Nitrogen			8			6					14
Phosphorus			3			6				3	12
Metals			11			1					12
Transformers											
Nitrogen			15			6					21
Phosphorus			4			6					10
Metals		1	7								8
Total		6	123			49	2			8	188

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.
** According to Cowardin et al. (1979).

nutrients and metals accumulated by plants with the fate of released materials.

53. Denitrification has been studied considerably, but the process is still poorly understood. Burial of material in sediments has been measured in several wetlands, most extensively in the Barataria Basin of Louisiana. Nutrient and heavy metal transformation have not been adequately studied. The importance of these processes cannot be assessed with the available information.

54. Fish and wildlife habitat. Fish and wildlife functions have been studied more intensively in this region than in any other (Table 9). Nearly 2,800 wetlands value references were identified. All wetland types were represented, but more than one-third of the studies were in estuarine wetlands. Extensive literature exists on mammals, birds, and fishes in all wetland systems, except for fishery studies in palustrine systems.

55. Primary productivity has been the subject of numerous studies in estuarine wetlands, and secondary productivity and energy flow have also been well studied. Comparatively few productivity studies have been conducted in palustrine wetlands.

CE workshop

56. Workshop participants stressed the need for a multidisciplinary approach, concentrating on thorough investigation of a limited number of field sites. They suggested that all functional assessments under such a holistic approach should be made within a socioeconomic context. Specifically, they recommended monetary evaluations of certain functions, including aspects of water quality and supply, commercial and recreational exploitation of fish and wildlife resources, and flood hazard reduction. Among research priorities not subject to direct monetary evaluation, food chain production, nutrient and pollutant processing, and aquatic habitat (including spawning and nursery habitat) were viewed as high priority. The panel ranked wetland types in descending order of priority as follows: freshwater marshes, bottomland hardwood forests, mangrove swamps, and forested and unforested freshwater tidal systems. Pocosins were also singled out as unique wetlands under significant pressure, and therefore worthy of special research attention.

Table 9

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 3

Wetlands Function	Wetland Type**					
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	Total
Wildlife habitat						
Mammals	29	47	18	3	37	134
Game	7	26	15	8	21	77
Nongame	1	1				2
Marine						
Endangered	2	2	1	1	1	7
Birds	66	169	13	12	97	357
Water birds	16	42			5	63
Raptors	1	8			6	15
Passerines		2			2	4
Game birds		5			11	16
Reptiles/amphibians	122	20	8	6	17	173
Waterfowl habitat	18	84		9	37	148
Aquatic habitat						
Fish	84	657	107	69	32	949
Crustaceans/molluscs	7	16	1			24
Productivity						
Energy		6				6
Primary productivity	3	22	5	2	7	39
Secondary productivity	3	23	2			28
Detritus						
General	140	330	96	92	80	738
Total	499	1,460	266	202	353	2,780

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Permit load

57. A total of 6,941 permit applications (42 percent of the national total) were received in 1982.

Research priorities

58. Hydrology. Research is needed to assess the role of:

a. Bottomland hardwoods in flood storage and desynchronization.

b. Freshwater marshes in flood storage and desynchronization.

c. Bottomland hardwoods in ground-water recharge/discharge.

d. Freshwater marshes in ground-water recharge/discharge.

e. Estuarine marshes in shoreline stabilization.

59. Water quality. Research is needed to assess the role of:

a. Bottomland hardwoods in nutrient uptake and heavy metal immobilization.

b. Freshwater marshes in nutrient uptake and heavy metal immobilization.

60. Fish and wildlife habitat. Research is needed to assess the role of:

a. Bottomland hardwoods in primary and secondary productivity.

b. Bottomland hardwoods as spawning and nursery habitat for aquatic biota.

c. Freshwater marshes in primary and secondary productivity.

d. Freshwater marshes as spawning and nursery habitat for aquatic biota.

61. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, workshop participants stressed that socioeconomic evaluations should be included in any multidisciplinary studies.

Region 4 - North Atlantic

District survey

62. Wetlands developmental pressures. More than 70 percent of the developmental pressures occurred in estuarine marshes (31 percent), swamps (20 percent), freshwater marshes (10 percent), and wet meadows (10 percent) (Figure 9).

63. Research needs. Functions assigned highest research priority were, in descending order: heavy metal immobilization; ground-water recharge/

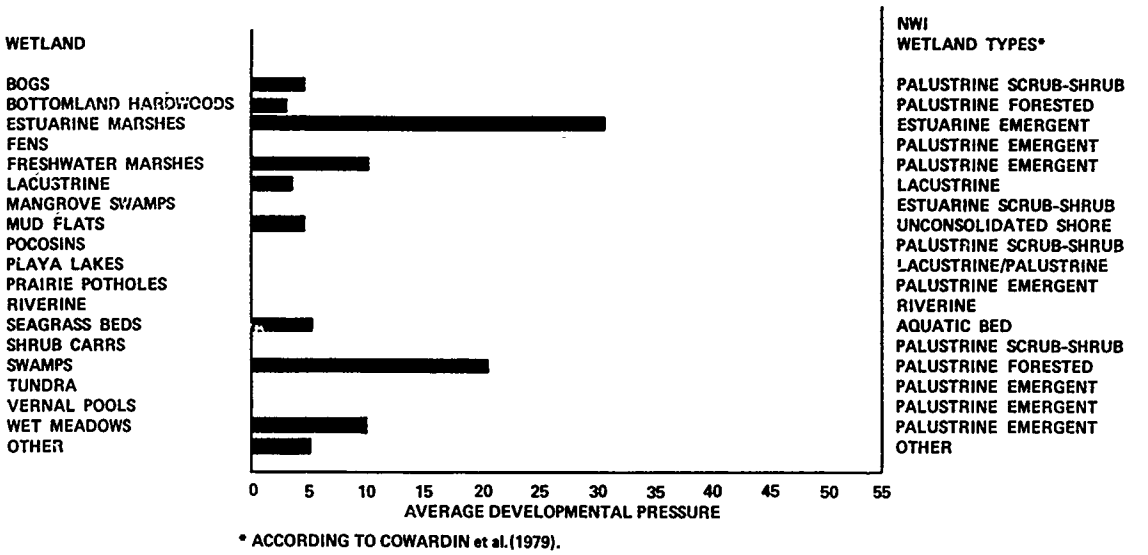


Figure 9. Average developmental pressure on wetland types, Region 4 - North Atlantic

discharge; nutrient uptake; food chain production; flood storage and desynchronization; reduction of suspended solids; aquatic habitat; and shoreline protection (Figure 10).

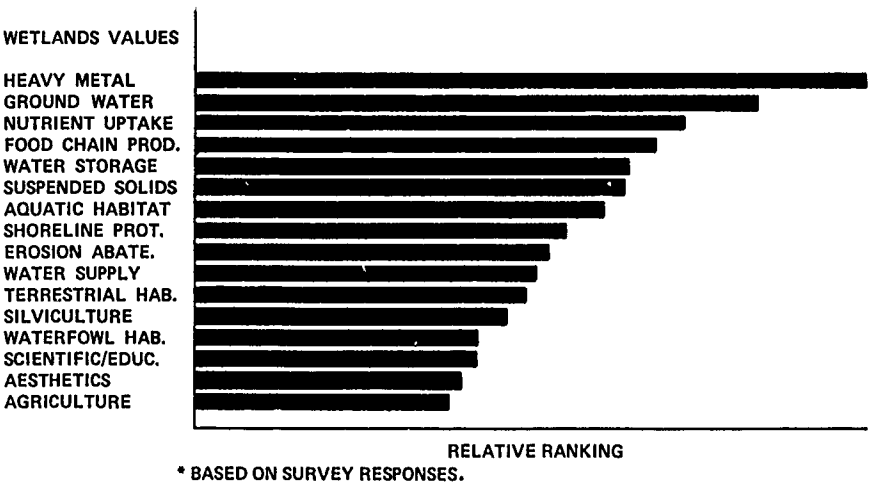


Figure 10. Relative ranking of wetlands research priorities, Region 4 - North Atlantic

Literature reviews

64. Hydrology. Sediment retention has been studied most intensely in estuarine wetlands, with very little information available on any other systems (Table 10). Flood storage and desynchronization has been well studied in palustrine and riverine systems, but little is known about this function in

Table 10

Number of Citations* of Wetlands Hydrologic Functions in Region 4

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception							
Evapotranspiration			1	3	9	1	14
Ground-water recharge			9	3	16	8	36
Ground-water discharge		1	6	2	8	3	20
Sediment retention	5	20	7	2	6	4	44
Flood storage and desynchronization		1	20	5	26	6	58
Shoreline anchoring	3	5	2	1	1		12
Water supply			3	3	6	3	15
General		1	2	2	2	14	21
Total	8	28	50	21	74	39	220

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** Cowardin et al. (1979).

other wetland types. Ground-water recharge/discharge studies have been concentrated in palustrine and riverine systems. Shoreline protection (anchoring) and water supply functions have not received much attention in any wetland types.

65. Water quality. More information is available on wetlands water quality in this region than in any other except the Gulf and South Atlantic Region (Table 11). However, few studies were sufficiently comprehensive to explain the interrelationships of system functions. Most research has been confined to estuarine emergent wetlands; little has been done in freshwater systems.

66. The literature review provided evidence that some wetlands accumulate and release various materials, generally resulting in alteration of water quality. Mass balances for nitrogen, phosphorus, or heavy metals were attempted at three sites, but these studies were incomplete. Knowledge of heavy metal behavior in all wetland types is also inadequate.

67. Considerable data described estuarine wetlands as sources and sinks. Most studies examined the role of estuarine and palustrine emergent wetlands vegetation in removing nutrients and heavy metals from water and/or sediments and their subsequent release. The only intensive denitrification study was conducted in an estuarine emergent marsh. This study may serve as a model for future denitrification research. Loss of materials from wetlands through long-term burial has received little attention. Accretion rates and sediment deposition have seldom been measured simultaneously at the same site to evaluate a particular wetland as a sink for nutrients or heavy metals. The role of wetlands in accreting suspended solids generally has been studied only in estuarine emergent wetlands. Few studies were identified that adequately assessed the role of wetlands as transformers, particularly in palustrine wetlands.

68. Fish and wildlife habitat. Relatively little wildlife information was located for lacustrine, riverine, or palustrine wetlands (Table 12). Estuarine systems have been studied much more than other systems, with major emphasis on birds and water birds. Palustrine wetlands are generally considered to be the most important wetlands in terms of wildlife use; however, wildlife values of these wetlands are not well known.

Table 11

Number of Citations* of Wetlands Water Quality Functions in Region 4

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen			4				1				5
Phosphorus			4								4
Metals			1								1
Sources											
N-fixation			5				1			4	10
Mobilization from sediment											
Nitrogen			6				1			2	9
Phosphorus			5							2	7
Metals			8			2	2			1	13
Exports											
Nitrogen			8				1			7	16
Phosphorus			8							7	15
Metals			6				1			1	8
Sinks											
Denitrification			2				1			1	4
Burial											
Nitrogen							1				1
Phosphorus			1								1
Metals			5			1	2				8
Uptake											
Nitrogen			9				1			7	17
Phosphorus			8							7	15
Metals			8			2	3		1	5	19
Transformers											
Nitrogen			7				1			4	12
Phosphorus			7								7
Metals			7								7
Total			109			5	16		1	48	179

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 12

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 4

Wetlands Function	Wetland Type**					
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	Total
Wildlife habitat						
Mammals	3	8	2		6	19
Game		7	2		6	15
Nongame		1	1		1	3
Marine						
Endangered	1	1			1	3
Birds	27	45	7	9	33	121
Water birds	8	14	1	2	4	29
Raptors		3	1			4
Passerines						
Game birds		7	2		8	17
Reptiles/amphibians	2	2	1	1	5	11
Waterfowl habitat	2	8	2	4	9	25
Aquatic habitat						
Fish	25	58	36	15	5	139
Crustaceans/molluscs	3	1				4
Productivity						
Energy		2				2
Primary productivity		5	1	1		7
Secondary productivity	1	2	1			4
Detritus						
General	25	48	23	7	13	116
Total	97	212	80	39	91	519

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

69. Aquatic habitat values of riverine, marine, and estuarine wetlands are relatively well known, especially for recreationally and commercially important species; however, information is limited for nongame and forage fishes. Little research is available on fish populations in lacustrine wetlands and nursery or spawning habitat in palustrine wetlands.

70. Primary and secondary productivity and energy flow have been described in some estuarine wetlands, but no specific information was found on detritus production and export. Productivity values were rarely examined in other wetland types.

CE workshop

71. A multidisciplinary, long-term, ecosystem approach was recommended. Each study would involve full hydrologic characterization, investigations of nutrient and pollutant dynamics, and productivity and habitat analyses. Socioeconomic studies were rated lowest priority. The panel suggested that all studies should be designed to provide results in a form useful for planning and regulatory processes. The panel noted that holistic studies may not be needed where existing information on a given site or topic is nearly complete and/or where specific supplemental studies are clearly appropriate.

72. The following were identified as priority wetland types, in descending order: swamps, estuarine marshes, and freshwater marshes.

Permit load

73. A total of 1,917 permits (12 percent of the national total) were received in 1982.

Research priorities

74. Hydrology. Research is needed to assess the role of:

a. Swamps in reducing suspended solids and in shoreline anchoring.

b. Freshwater marshes in reducing suspended solids and in shoreline anchoring.

c. Estuarine marshes in shoreline anchoring.

Although information is available on ground-water recharge and discharge in palustrine wetlands, the Districts have repeatedly listed these functions as important research needs. Reexamination of the quality and applicability of available literature is recommended.

75. Water quality. Research is needed to assess the role of:

a. Swamps in heavy metal immobilization and nutrient uptake.

b. Freshwater marshes in heavy metal immobilization and nutrient uptake.

Estuarine marshes are subjected to the greatest developmental pressures, and water quality functions are a major concern. However, the literature review indicated that substantial information is available on these functions. Reexamination and synthesis of this literature are necessary before additional research is recommended.

76. Fish and wildlife. Research is needed to assess the role of:

a. Swamps as fish spawning and nursery habitat and in food chain production.

b. Estuarine marshes in food chain production.

c. Freshwater marshes as fish spawning and nursery habitat and in food chain production.

77. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, these rankings do not imply that socioeconomic functions are of little importance. Instead, they are not considered to be immediate District needs. Therefore, only limited socioeconomic studies will be conducted during initial years of wetlands values research, unless they are incorporated into a multidisciplinary approach.

Region 5 - Interior: North Central-Great Lakes

District survey

78. Wetlands developmental pressures. Greatest wetlands developmental pressures occurred in freshwater marshes (32 percent), prairie potholes (17 percent), wet meadows (13 percent), lacustrine (12 percent), and swamps (11 percent) (Figure 11).

79. Research needs. Functions assigned highest research priority were, in descending order: flood storage and desynchronization; nutrient uptake; ground-water recharge/discharge; heavy metal immobilization; reduction of suspended solids; food chain production; water supply; and erosion abatement (Figure 12).

Literature reviews

80. Hydrology. Some of the most specific information available concerning wetlands hydrology is available for this region (Table 13). Studies in

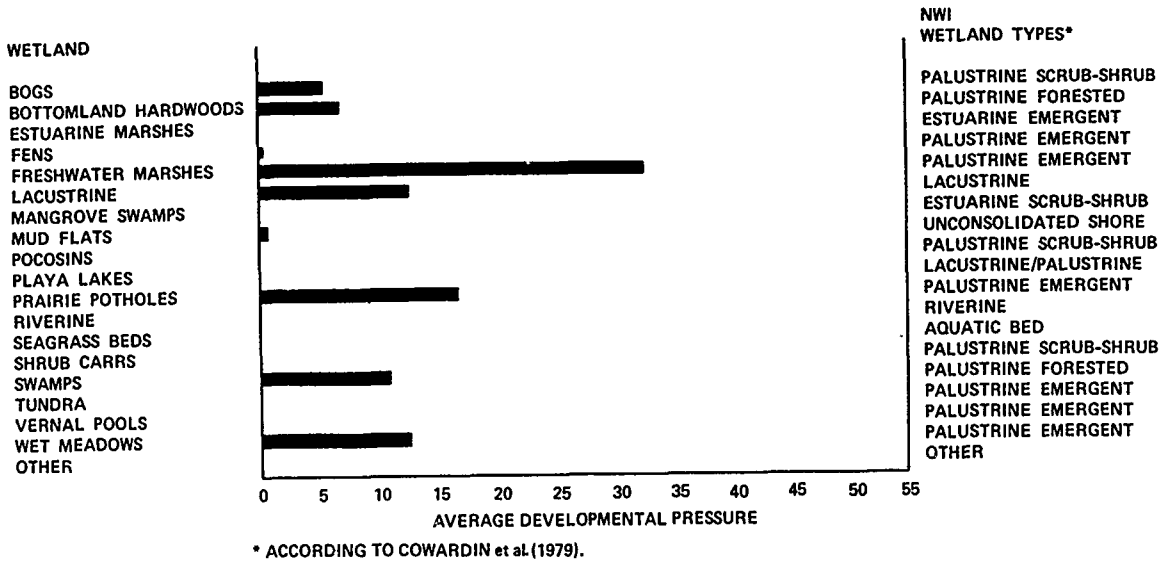


Figure 11. Average developmental pressure on wetland types, Region 5 - Interior: North Central-Great Lakes

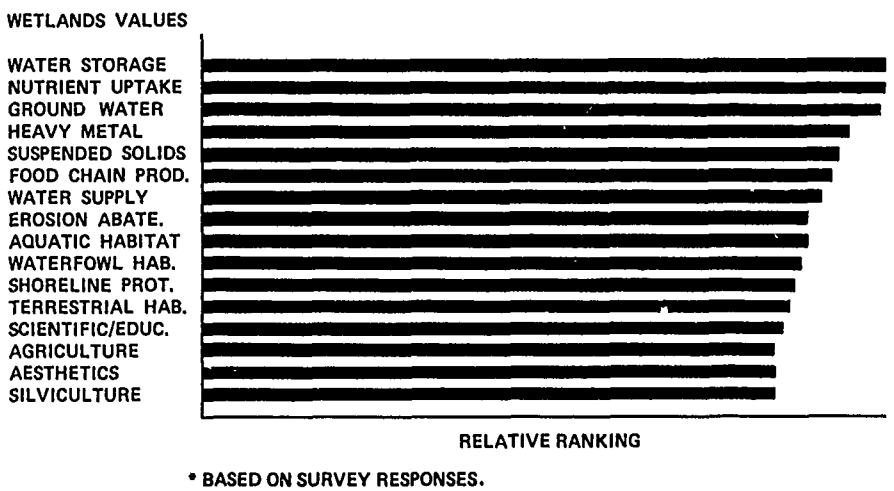


Figure 12. Relative ranking of wetlands research priorities, Region 5 - Interior: North Central-Great Lakes

Table 13

Number of Citations* of Wetlands Hydrologic Functions in Region 5

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception				1			1
Evapotranspiration			2	7	18	8	35
Ground-water recharge			16	27	48	10	101
Ground-water discharge			8	10	14	9	41
Sediment retention			12	9	17	4	42
Flood storage and desynchronization			19	17	46	11	93
Shoreline anchoring			2	7	2		11
Water supply			0	0	2	2	4
General			1	5	1	1	8
Total			60	83	148	45	336

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

palustrine emergent wetlands (bogs and prairie potholes) have provided detailed information on various water budget components, including interception, evapotranspiration, and ground-water movement. The role of wetlands in shoreline stabilization and sediment retention has been examined at a general level, but few quantitative studies are available. Flood storage and desynchronization has been investigated to a limited extent (primarily in the Great Lakes region), but downstream effects of large-scale drainage efforts have not been evaluated. Detailed hydrologic studies have focused on a few specific palustrine emergent systems (bogs and prairie potholes), while little information is available on other palustrine emergent, palustrine forested, lacustrine, or riverine wetlands.

81. Water quality. Little information was found on water quality functions (Table 14). Major studies have been conducted in only three states. Most water quality studies have concentrated on nutrient dynamics, with little attention given to the role of wetlands in the processing or storing of heavy metals.

82. Three mass balance studies quantified long-term estimates for annual inputs, outputs, and net uptake of nutrients. However, mass balance studies were hampered by difficulties in relating nutrient measurements to hydrologic data, and none of the studies included heavy metals.

83. Little research was found that integrated plant productivity with leaching and decomposition to estimate the potential of wetlands to act as sources. No published measurements of nitrogen fixation were found. Some studies provided evidence that wetland plants mobilized metals from sediments.

84. No direct quantification of either denitrification or water quality improvement due to burial of nutrients and metals was found. Several studies on wastewater treatment capacity and nutrient enrichment indicated that wetlands are effective sinks for nitrogen and phosphorus. Few studies have been conducted on wetlands as transformers of either nutrients or metals.

85. Fish and wildlife habitat. Wetlands use by mammals, birds (including waterfowl), and fishes has been relatively well documented, except for the use of palustrine wetlands by fishes (Table 15). Productivity values of wetlands have not been well documented, and identified studies were related to primary productivity. Empirical data are largely lacking for productivity

Table 14

Number of Citations* of Wetlands Water Quality Functions in Region 4

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen							4	1			5
Phosphorus							4	1		4	9
Metals											
Sources											
N-fixation						1	1				2
Mobilization from sediment											
Nitrogen							1			1	2
Phosphorus							1			1	2
Metals										4	4
Exports											
Nitrogen											
Phosphorus											
Metals											
Sinks											
Denitrification											
Burial											
Nitrogen											
Phosphorus											
Metals											
Uptake											
Nitrogen				1	2	2	5	1		4	15
Phosphorus				1	1	2	5	1		4	14
Metals						1				3	4
Transformers											
Nitrogen							1				1
Phosphorus				1	1		1				3
Metals											
Total				3	4	6	23	4		21	61

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.
** According to Cowardin et al. (1979).

Table 15

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 5

Wetlands Function	Wetland Type**					
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	Total
Wildlife habitat						
Mammals			5	2	17	24
Game			2	2	5	9
Nongame						
Marine						
Endangered						
Birds			17	55	124	196
Water birds			1	7	13	21
Raptors				1	1	2
Passerines						
Game birds			2	2	25	29
Reptiles/amphibians			6	6	14	26
Waterfowl habitat			7	31	68	106
Aquatic habitat						
Fish			135	315	19	469
Crustaceans/molluscs						
Productivity						
Energy						
Primary productivity			4	3	2	9
Secondary productivity						
Detritus						
General			47	95	54	196
Total			226	519	342	1,087

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

values (primary and secondary productivity, detritus production, and energy flow) in all wetland types.

CE workshop

86. The workshop panel emphasized the need for intensive investigation of hydrology and water quality using a mass balance approach. Stress manipulations should be included when feasible. If complete characterization is not possible, the panel recommended that ground-water dynamics and flood storage and desynchronization receive highest priority (in that order). No research priority was assigned to fish and wildlife or socioeconomic values.

87. Three wetland types identified as needing particular research attention were, in descending order of priority: palustrine forests and marshes adjacent to riverine systems and small lakes; prairie potholes; and reservoirs.

Permit load

88. A total of 2,224 permit applications (13 percent of the national total) were received in 1982.

Research priorities

89. Hydrology. Research is needed to assess the role of palustrine forests and marshes adjacent to rivers and small lakes in:

a. Shoreline stabilization and erosion abatement.

b. Ground-water recharge/discharge.

c. Flood storage and desynchronization.

Although hydrologic studies in prairie potholes were identified by CE workshop participants as a significant research need, considerable hydrologic data were identified for this system (Table 13). Therefore, additional studies are not recommended until available hydrologic information has been synthesized for this wetland type.

90. Water quality. Research is needed to assess the role of:

a. Palustrine wetlands adjacent to rivers and lakes in nutrient uptake and immobilization of heavy metals.

b. Prairie potholes in nutrient uptake.

91. Fish and wildlife habitat. Research is needed to assess the role of palustrine wetlands adjacent to rivers and small lakes in:

a. Food chain production

b. Spawning and nursery habitat for aquatic biota.

92. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, these rankings do not imply that socioeconomic functions are of little importance. Instead, they are not considered to be immediate District needs. Therefore, only limited socioeconomic studies will be conducted during initial years of wetlands values research.

Region 6 - Interior: Desert Steppe

District survey

93. Wetlands developmental pressures. More than 80 percent of the developmental pressures occurred in freshwater marshes (48 percent), wet meadows (19 percent), and lacustrine habitats (17 percent) (Figure 13).

94. Research needs. Functions assigned highest research priority were, in descending order: ground-water recharge/discharge; heavy metal immobilization; water supply; food chain production; reduction of suspended solids; nutrient uptake; erosion abatement; and flood storage and desynchronization (Figure 14).

Literature reviews

95. Hydrology. No wetlands hydrologic functions have been thoroughly investigated, although some specific references were found on evapotranspiration. Wetlands ground-water recharge/discharge, erosion abatement, flood storage and desynchronization, and water supply functions are poorly understood. Literature on lacustrine systems is particularly lacking (Table 16).

96. Water quality. No literature was found on wetlands water quality.

97. Fish and wildlife habitat. Most research has been conducted on birds and fishes of riverine systems and their adjacent wetlands (Table 17). However, the importance of these systems to other wildlife, particularly mammals, water birds, and waterfowl, is not well documented. Few wildlife studies in lacustrine wetlands were found. Many studies examining wildlife use of palustrine wetlands focused on the role of those wetlands in maintaining regional avian diversity, and only a few studies addressed the use of palustrine wetlands by mammals, reptiles, and amphibians. Palustrine studies appear to be concentrated primarily in the lower Colorado, Rio Grande, and Snake Rivers and the California central valley.

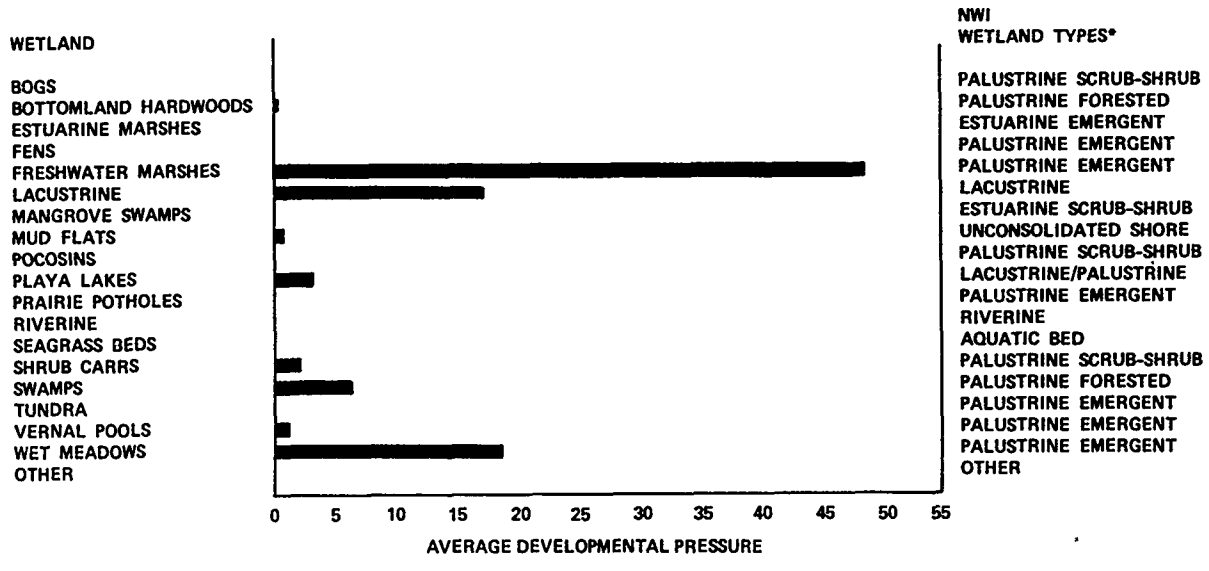


Figure 13. Average developmental pressure on wetland types, Region 6 - Interior: Desert Steppe

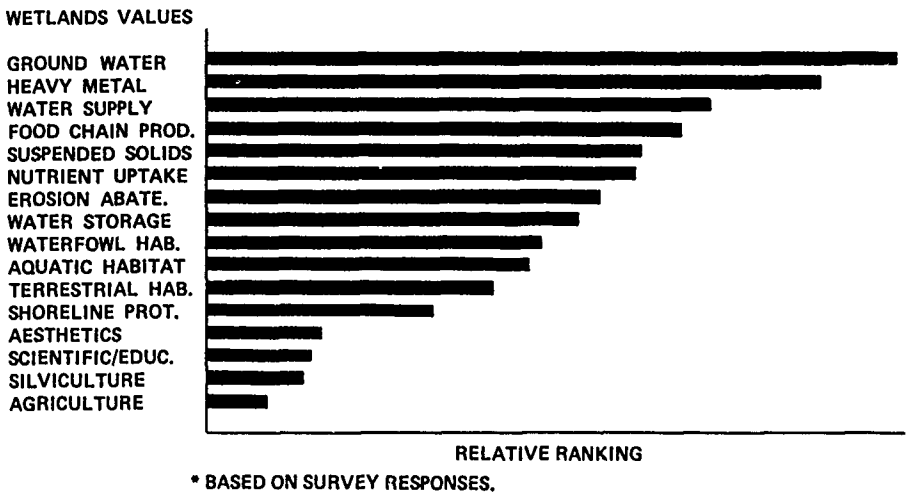


Figure 14. Relative ranking of wetlands research priorities, Region 6 - Interior: Desert Steppe

Table 16

Number of Citations* of Wetlands Hydrologic Functions in Region 6

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception							
Evapotranspiration			3	1	7	4	15
Ground-water recharge			2	2	3		7
Ground-water discharge			2		3	1	6
Sediment retention			3	1	4		8
Flood storage and desynchronization			1	1	2		4
Shoreline anchoring			1		1	1	3
Water supply					1	2	3
General					1	1	2
Total			12	5	22	9	48

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 17

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 6

Wetlands Function	Wetland Type**					
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	Total
Wildlife habitat						
Mammals			6	1	6	13
Game			4		3	7
Nongame			2		2	4
Marine						
Endangered			2			2
Birds			16	12	42	70
Water birds			2	2	3	7
Raptors			1	1	1	3
Passerines					1	1
Game birds			3	2	13	18
Reptiles/amphibians			3	2	5	10
Waterfowl habitat			5	6	5	16
Aquatic habitat						
Fish			163	50	14	227
Crustaceans/molluscs						
Productivity						
Energy						
Primary Productivity				1		1
Secondary Productivity				1		1
Detritus						
General			37	19	27	83
Total			244	97	122	463

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

98. Use of riverine wetlands by fishes is comparatively well documented, and population studies have been conducted in most major river systems. Lacustrine wetland studies generally have been confined to a few large reservoirs (e.g. Flaming Gorge and Lake Powell) and some smaller lakes in Colorado and Utah. Fishery studies in palustrine wetlands are scarce.

99. Productivity values have not been studied in riverine or palustrine systems. Only one reference each was found for primary and secondary productivity values in lacustrine systems.

CE workshop

100. Hydrologic functions were rated as the highest research priority, and particular studies were suggested on water supplies, ground-water dynamics, flood storage and desynchronization, and erosion abatement. Priorities were not assigned to any water quality values, except for the effects of turbidity on trout and salmon spawning habitat. Fish and wildlife habitat values of palustrine emergent wetlands were a major concern. Studies were suggested on the use of these relatively scarce wetlands by nongame species and by big game and waterfowl as wintering habitat. Assessment of fish and wildlife habitat values of agricultural wetlands was also suggested. The panel also recommended that socioeconomic values be derived for both hydrologic and fish and wildlife habitat functions within the context of recommended studies.

Permit load

101. A total of 467 permit applications (3 percent of the national total) were received in 1982.

Research priorities

102. Hydrology. Research is needed to assess the role of palustrine emergent wetlands in:

a. Ground-water recharge/discharge.

b. Reduction of suspended solids.

c. Erosion abatement.

d. Flood storage and desynchronization.

103. Water quality. Research is needed to assess the role of palustrine emergent wetlands in nutrient uptake and heavy metal immobilization.

104. Fish and wildlife habitat. Research is needed to assess the role of palustrine wetlands in:

a. Wintering waterfowl.

b. Wintering big game species.

105. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, the workshop panel indicated a need to include socioeconomics in the context of any conducted research. Monetary assessment is premature until a better understanding of the functions of wetlands is achieved. Consequently, substantive socioeconomic studies will be postponed until later.

Region 7 - Interior: Midcentral

District survey

106. Wetlands developmental pressures. More than 53 percent of the developmental pressures occurred in bottomland hardwoods, 14 percent in swamps, and 10 percent in freshwater marshes (Figure 15).

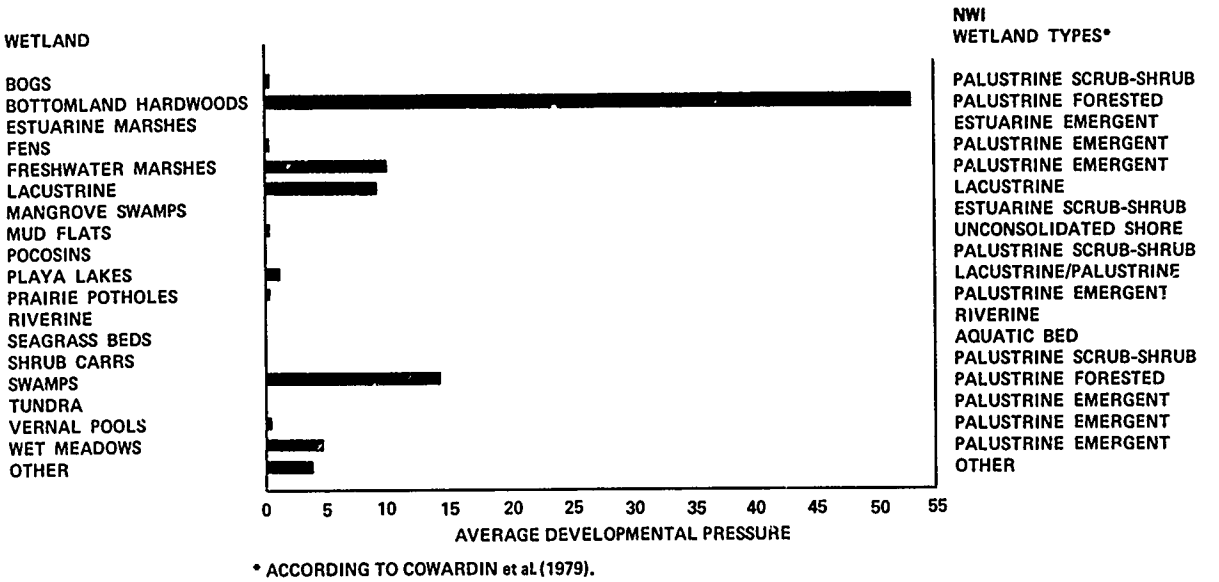
107. Research needs. Functions assigned highest research priority were, in descending order: food chain production; reduction of suspended solids; nutrient uptake; heavy metal immobilization; flood storage and desynchronization; ground-water recharge/discharge; aquatic habitat; and erosion abatement (Figure 16).

Literature reviews

108. Hydrology. Relatively little hydrologic research has been conducted in this region (Table 18). Flood storage and desynchronization has received most attention, primarily in palustrine wetlands. Few studies were found on other hydrology functions.

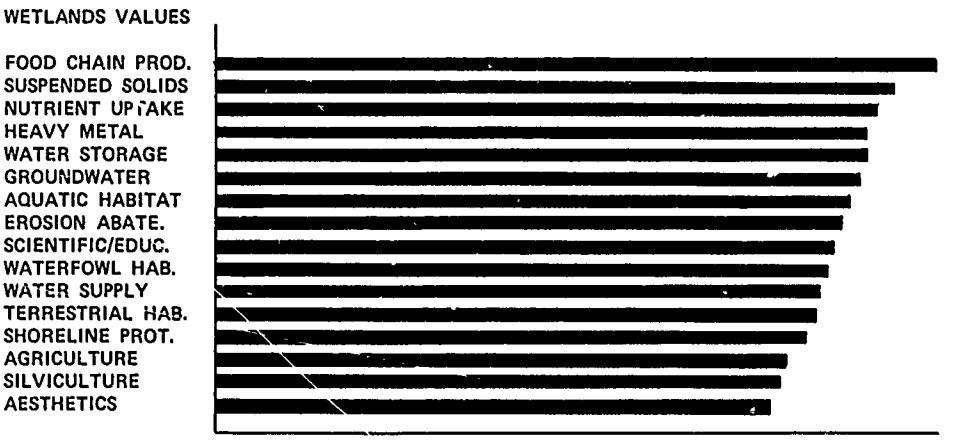
109. Water quality. Few water quality studies were identified (Table 19). Significant studies have been conducted in only three states. These studies concentrated on the role of wetlands in various aspects of nutrient dynamics, but virtually no work has been conducted on heavy metals.

110. Two relatively informative mass balance studies have been conducted; both studies considered phosphorus and one considered nitrogen dynamics. Other attempts at mass balance measurements were inadequate due to difficulties in establishing reliable water budgets.



* ACCORDING TO COWARDIN et al (1979).

Figure 15. Average developmental pressure on wetland types, Region 7 - Interior: Midcentral



* BASED ON SURVEY RESPONSES.

Figure 16. Relative ranking of wetlands research priorities, Region 7 - Interior: Midcentral

Table 18

Number of Citations* of Wetlands Hydrologic Functions in Region 7

Wetlands Function	Wetland Type**						
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	General	Total
Interception						1	1
Evapotranspiration				1	4	1	6
Ground-water recharge			2		7	3	12
Ground-water discharge					5	2	7
Sediment retention			3	2	2	3	10
Flood storage and desynchronization			11	6	16	2	35
Shoreline anchoring			1	3		1	5
Water supply					1		1
General			2	2	8	7	19
Total			19	14	43	20	96

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

Table 19

Number of Citations* of Wetlands Water Quality Functions in Region 7

	Wetland Type**										
		Estuarine				Palustrine					
Wetlands Function	Marine	Scrub/ Shrub	Emergent	Riverine Emergent	Lacustrine Emergent	Forested	Scrub/ Shrub	Moss/ Lichen	Aquatic Bed	Emergent	Total
Mass balance											
Nitrogen						1				1	2
Phosphorus						1				1	2
Metals											
Sources											
N-fixation											
Mobilization from sediment											
Nitrogen				2	1					1	4
Phosphorus				2	1	1					4
Metals											
Exports											
Nitrogen				1	5	1				2	9
Phosphorus				1	4	2				2	9
Metals											
Sinks											
Denitrification											
Burial											
Nitrogen											
Phosphorus						1					1
Metals											
Uptake											
Nitrogen				2						2	4
Phosphorus				2	2	2				2	8
Metals											
Transformers											
Nitrogen										1	1
Phosphorus						1					1
Metals											
Total				10	13	10				12	45

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.
** According to Cowardin et al. (1979).

111. Studies of wetlands as sources of nutrients have been confined to assessment of the ability of higher plants to mobilize nutrients from sediments and release them at the surface through leaching and remineralization. Studies of wetlands as sinks for nutrients and heavy metals were considered inadequate because they either did not measure denitrification properly; evaluate long-term removal of nutrients and metals by burial in sediments; quantify concentrations of nitrogen, phosphorus, and heavy metals in soils; or measure nitrogen fixation. Two studies addressed some aspects of nutrient transformation but, overall, data were lacking.

112. Fish and wildlife habitat. Research on wildlife in riverine and lacustrine wetlands has concentrated primarily on avian species other than waterfowl (Table 20). Palustrine wetland studies, mostly in forested systems, have demonstrated the value of these wetlands to game mammals, furbearers, nongame mammals, wading birds, and passerine birds. Most of the work was general and reflected a need for greater specificity, especially for studies on raptors, reptiles, and amphibians. Although an important resource, waterfowl were not well studied in any wetland type.

113. Due to the considerable amount of riverine and lacustrine habitat, numerous studies have been conducted on fisheries, especially on reservoir fishes and endangered species of the Ohio, Mississippi, and Tennessee river systems. The importance of palustrine forested wetlands to fishes has not been well documented.

114. Wetlands productivity values have been poorly studied. All studies pertained to primary productivity. Secondary productivity, energy flow, and detritus production are all relatively undocumented.

CE workshop

115. Representatives of the western section of the region considered water quality to be the highest priority, particularly problems associated with suspended solids and agricultural runoff. Their rankings of hydrologic and fish and wildlife research needs coincided closely with those derived from the survey, except less emphasis was placed on the need for productivity studies. The panel recommended that socioeconomic studies be incorporated into research to quantify values of identified wetlands functions. Bottomland hardwood forests were designated as the highest priority wetland type.

Table 20

Number of Citations* of Wetlands Fish and Wildlife Functions in Region 7

Wetlands Function	Wetland Type**					Total
	Marine	Estuarine	Riverine	Lacustrine	Palustrine	
Wildlife habitat						
Mammals			3	2	16	21
Game			3	3	7	13
Nongame			1		2	3
Marine						
Endangered			1			1
Birds			14	10	53	77
Water birds			3	2	5	10
Raptors					1	1
Passerines			2	1	4	7
Game birds			3	2	20	25
Reptiles/amphibians			2	2	6	10
Waterfowl habitat			6	3	11	20
Aquatic habitat						
Fish			143	150	14	307
Crustaceans/molluscs						
Productivity						
Energy						
Primary productivity			5	2	5	12
Secondary productivity						
Detritus						
General			43	30	41	114
Total			229	207	185	621

* Not necessarily different articles, since some individual articles address many functions and/or wetland types.

** According to Cowardin et al. (1979).

116. Representatives from the eastern section of the region identified the top five research priorities as: food chain production; suspended solids; fishing/hunting/recreation; nutrient uptake; and pollutant processing (including heavy metals). Hydrologic functions were assigned a very low priority. They concurred with priority wetland types identified in the survey, except that riverine systems should be considered a high priority despite their apparently low level of developmental pressure.

Permit load

117. A total of 2,953 permit applications (18 percent of the national total) were received in 1982.

Research priorities

118. Hydrology. Research is needed to assess the role of:

a. Bottomland hardwoods in sediment retention, ground-water recharge/discharge, shoreline anchoring, and erosion abatement.

b. Swamps in sediment retention and ground-water recharge/discharge.

c. Palustrine systems adjacent to rivers in sediment retention.

Flood storage and desychronization in bottomland hardwoods and swamps is believed to be particularly important. The literature indicated that this function has received considerable attention. Therefore, reexamination and synthesis of the literature should be conducted before additional research is recommended.

119. Water quality. Research is needed to assess the role of:

a. Bottomland hardwoods in nutrient uptake and heavy metal immobilization.

b. Swamps in nutrient uptake and heavy metal immobilization.

c. Palustrine systems adjacent to rivers in nutrient uptake and heavy metal immobilization.

120. Fish and wildlife habitat. Research is needed to assess the role of:

a. Bottomland hardwoods in food chain production, as fish spawning and nursery habitat, and as waterfowl habitat.

b. Swamps in food chain production, as fish spawning and nursery habitat, and as waterfowl habitat.

c. Palustrine systems adjacent to rivers as fish spawning and nursery habitat and in food chain production.

121. Socioeconomics. Survey respondents ranked the four socioeconomic functions among the five lowest priority research needs. However, these rankings do not imply that socioeconomic functions are of little importance. Instead, specific research is not considered to be an immediate District need. However, the workshop participants recommended that socioeconomic evaluations be regarded as integral to other investigations of wetlands functions.

PART IV. NATIONAL RESEARCH PRIORITIES

122. This part of the study plan presents national wetlands functions and values research priorities. The approach used to establish priorities and types of studies needed to address the priorities are also included. Regional research priorities presented in Part III were developed to provide the most comprehensive view of research needs. National priorities were developed from regional priorities to focus on research needs of greatest significance and to avoid duplication of research when several regions identified the same needs. Criteria used for identifying national research priorities are presented below.

Criteria for Establishing Priorities

123. The following criteria were used to identify national wetlands functions and values research priorities:

a. Priority wetland types. Priority wetland types are those widely distributed in one or more regions.

b. Degree of developmental pressures. Wetland types receiving greatest developmental pressures were assigned high research priority.

c. Data gaps. The quantity and quality of wetlands values literature varied among wetland types and functions. Highest research priority was assigned to wetland types and functions having the most critical data gaps.

Primary sources of information used for implementing the above criteria included the CE survey, CE workshop, and literature reviews. Less, but significant, emphasis was placed on results of a national analysis of wetlands distribution (Frayer et al. 1983), the FWS workshop (Sather and Stuber 1983), and other national workshops and symposia.

Types of Studies

124. Four types of studies have been identified to address national priority research, including:

a. Holistic studies.

b. Function-specific studies.

c. Special studies.

d. Socioeconomic studies.

Holistic studies

125. Holistic studies will consist of comprehensive, long-term research efforts that examine several interrelated wetlands functions at representative sites in priority wetland types. Such studies will be conducted by interdisciplinary teams for a sufficient period to:

a. Assess the ability of the wetland type to perform each priority function and identify diagnostic characteristics for each function.

b. Quantify the degree to which the wetland type performs each function.

Holistic studies are necessary because wetlands functions are interrelated. For example, adequate assessment of the ability of a wetland type to perform nutrient uptake functions requires characterization of both water budget and food chain relationships. Failure of most previous studies to examine such interrelationships has limited the usefulness of the resulting data.

126. Selected study sites will be monitored for a minimum of 3 years. Studies will be designed to assess the ability of each wetland type to perform the priority functions in each hydrologic regime (zone) present at the study sites. Laboratory and modeling studies may be included to complement field research.

127. Priority wetland types. The following wetland types were identified for holistic studies, in descending order of priority:

a. Bottomland hardwoods in the Interior: Midcentral (Lower Mississippi Valley) and the Gulf and South Atlantic Coasts (eastern Coastal Plain) regions.

b. Freshwater marshes adjacent to rivers and lakes in the Interior: North Central-Great Lakes region.

c. Estuarine marshes in the Pacific Coast region.

d. Swamps in the North Atlantic region.

e. Tundra in the Alaska region.

128. Priority wetlands functions. The following functions will be examined in each priority wetland type:

a. Hydrology.

(1) Water budget, including ground-water recharge/discharge.

(2) Flood storage and desynchronization.

(3) Sediment trapping and retention.

(4) Shoreline anchoring and erosion abatement.

b. Water quality.

(1) Mass balance analysis of nutrients and heavy metals.

(2) Denitrification.

c. Fish and wildlife.

(1) Primary and secondary productivity.

(2) Detrital export.

(3) Spawning and nursery habitat for aquatic biota.

Function-specific studies

129. Certain regional wetland types receiving intense developmental pressures have been well studied with respect to some critical wetlands functions, while knowledge of other functions is lacking. The lack of information regarding critical functions limits the quality of overall assessments of values in these wetland types. In such cases, holistic studies are not needed; instead, studies of particular functions should be conducted. Function-specific studies are presented below by wetlands function and type, in descending order of priority:

a. Hydrologic and water quality functions in pocosins of the Gulf and South Atlantic Coasts region.

b. Habitat functions for wintering big game species in riparian wetlands bordering small streams in mountain valleys of the Interior: Desert Steppe region.

c. Spawning and nursery habitat for fishes in freshwater tidal marshes and swamps in the Gulf and South Atlantic Coasts and North Atlantic regions.

d. Water quality and hydrologic functions of prairie potholes in the Interior: North Central-Great Lakes region.

Special studies

130. Studies should be conducted to address special research needs. Two types of special studies have been identified:

a. Synthesis of particular wetlands functions and values data. In some cases, CE personnel identified research needs for particular functions in wetland types for which extensive literature is already available. This suggested that the literature is not in a form that can be readily utilized. For example, CE personnel in the North Atlantic identified a need for research on water quality functions in estuarine marshes, which are subjected to intense developmental pressures. However, these functions have been extensively studied in this wetland type. Following is a

list of synthesis studies that should be conducted, in descending order of priority by wetlands function and type:

(1) Hydrologic functions in bottomland hardwoods of the Interior: Midcentral region.

(2) Water quality functions in estuarine marshes of the North Atlantic region.

(3) Ground-water recharge/discharge in swamps of the North Atlantic region.

These short-term research efforts will be conducted through workshops and/or by regional wetlands values experts.

b. Studies of altered wetlands in the Pacific Coast region. Studies should be conducted to determine the ability of diked wetlands in the Pacific Coast region to perform various wetlands functions. Field studies and/or synthesis studies will be conducted, as appropriate.

Socioeconomic studies

131. Basic knowledge of many wetlands functions is lacking. It is premature to initiate socioeconomic studies designed to result in either monetary or nonmonetary techniques for assessing these functions. Therefore, socioeconomic studies will be delayed until more information is available on the functions performed by priority wetland types. An economist will be included in interdisciplinary teams conducting holistic studies to ensure that proposed research provides data compatible with economic assessments. Once an adequate understanding of wetlands functions is achieved, monetary techniques will be developed to assess these functions.

Research Priorities

132. National research priorities are presented in Table 21 by wetland type and function, arranged in descending order of priority. Socioeconomic studies and all other research needs identified in the regional summaries (Part III) are also included, but regional research needs are not prioritized.

Table 21

National Wetlands Functions and Values

Research Priorities

Priority	Wetland Type and Function
1	Bottomland hardwoods (Gulf and South Atlantic Coasts and Interior: Midcentral) o Synthesis study of hydrologic functions
2	Bottomland hardwoods, including swamps (Gulf and South Atlantic Coasts and Interior: Midcentral) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota o Waterfowl habitat
3	Freshwater marshes (Interior: North Central-Great Lakes) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota
4	Estuarine marshes (North Atlantic) o Synthesis study of water quality functions
5	Swamps (North Atlantic) o Synthesis study of ground-water recharge/discharge
6	Estuarine marshes (Pacific Coast) o Ground-water recharge/discharge o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota

(Continued)

Table 21 (Continued)

Priority	Wetland Type and Function
7	Swamps (North Atlantic) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota
8	Riparian forests (Interior: Desert Steppe) o Winter habitat for big game species
9	Tundra (Alaska) o Ground-water recharge/discharge o Flood storage and desynchronization o Sediment retention o Shoreline anchoring and erosion abatement o Nutrient uptake o Denitrification o Heavy metal immobilization o Food chain production o Detrital export o Spawning and nursery habitat for aquatic biota o Migratory waterfowl habitat
10	Pocosins (Gulf and South Atlantic Coasts) o Hydrology o Water quality
11	Freshwater tidal marshes and swamps (Gulf and South Atlantic Coasts and North Atlantic) o Spawning and nursery habitat for aquatic biota
12	Prairie potholes (Interior: North Central-Great Lakes) o Hydrology o Water quality
13	Altered wetlands (Pacific Coast) o Hydrology o Water quality o Fish and wildlife

Socioeconomic Studies

These studies will be conducted for all implemented research priorities. The studies will be implemented when investigated functions are better understood. Both monetary and nonmonetary values assessments will be investigated.

(Continued)

Table 21 (Continued)

Other Identified Research Needs

Other identified research needs are presented below by region, wetland type, and function. No attempt was made to assign priorities to these needs.

Region 1 - Alaska

Bogs
- o Habitat for migratory waterfowl

Estuarine marshes
- o Food chain production
- o Spawning and nursery habitat for aquatic biota

Region 2 - Pacific Coast

Freshwater marshes
- o Ground-water recharge/discharge
- o Flood storage and desynchronization
- o Sediment retention
- o Nutrient uptake
- o Heavy metal immobilization
- o Food chain production
- o Wildlife habitat
- o Aquatic habitat

Riparian forests
- o Flood storage and desynchronization
- o Sediment retention

Region 3 - Gulf and South Atlantic Coasts

Freshwater marshes
- o Ground-water recharge/discharge
- o Flood storage and desychronization
- o Nutrient uptake
- o Heavy metal immobilization
- o Food chain production
- o Aquatic habitat

Estuarine marshes
- o Shoreline anchoring and erosion abatement

Region 4 - North Atlantic

Freshwater marshes
- o Sediment retention
- o Shoreline anchoring and erosion abatement
- o Nutrient uptake
- o Heavy metal immobilization
- o Food chain production
- o Aquatic habitat

Estuarine marshes
- o Shoreline anchoring and erosion abatement
- o Food chain production

(Continued)

Table 21 (Concluded)

Region 5 - Interior: North Central-Great Lakes

None

Region 6 - Interior: Desert Steppe

Freshwater marshes

- o Ground-water recharge/discharge
- o Flood storage and desynchronization
- o Sediment retention
- o Shoreline anchoring and erosion abatement
- o Nutrient uptake
- o Heavy metal immobilization
- o Wintering waterfowl habitat

Region 7 - Interior: Midcentral

None

PART V: ASSESSMENT TECHNIQUE DEVELOPMENT

133. The FHWA Technique (Adamus 1983) is the only identified comprehensive wetlands evaluation technique that can be readily adapted to CE needs. This technique, designed primarily for highway planners, has substantial potential for application by the CE. It permits the user to assess the opportunity, effectiveness, and significance of a wetland in the performance of a particular wetlands function. Assessments are expressed in terms of a high, moderate, or low probability that the wetland provides a particular function.

134. The FHWA Technique has many characteristics that were identified by the CE District survey as desirable. It is direct, examines all known wetlands functions, assesses one or more wetland areas, is flexible enough to provide different levels of precision based on different levels of available information, and is reasonably repeatable. The procedure is based on information in the technical literature. This characteristic is both a major strength and a principal constraint. Since the technique is based on available literature, its use provides the most technically valid conclusions. Conversely, data gaps represent inherent weaknesses. Results of research proposed in the study plan will substantially reduce the number of data gaps and thereby strengthen the technique.

135. Several refinements, modifications, and improvements are necessary before the FHWA Technique is ready for field use. Principal among these are the need for literature updating, computerization, addition of a mechanism for sensitivity analysis, regionalization, and field testing.

Literature Updating

136. The FHWA Technique presently incorporates data available through 1981 (Adamus and Stockwell 1983). Updating of the literature to the present, and annual updating thereafter, will be conducted to improve validity within constraints imposed by the literature.

Computerization

137. The technique currently must be implemented manually, which is both cumbersome and time consuming. Development of computer software will essentially eliminate this undesirable feature. The program will be written in FORTRAN 77 using MS-DOS as the operating system. Software will be designed for use with microcomputers and will include features for interacting with larger databases.

Sensitivity Analysis

138. The technique presently provides the user with a high, moderate, or low probability that a wetland provides a particular function. However, it does not provide any level of confidence in the assigned values. The sensitivity analysis will incorporate a mechanism to reflect a level of confidence in the conclusion.

Regionalization

139. Regionalization of the FHWA Technique will simplify the procedure, improve the reliability of conclusions, and incorporate red flag features. A screening feature will be incorporated to eliminate inapplicable and unnecessary procedures, thus reducing the laboriousness of the system. This feature will assess the quality of local data and lessen the probability of erroneous interpretations. The red flag feature will allow users to focus on regional wetlands values of critical significance (e.g. presence of endangered species).

Field Testing

140. Field tests will be conducted in a variety of wetland situations, and the results will be used to revise the evaluation technique. Field testing and revision will be an iterative process to ensure a current, technically sound system that is useful to CE field elements.

PART VI: TECHNOLOGY TRANSFER

141. The purpose of this part of the study plan is to present proposed methods for transferring the technology resulting from wetlands values research to CE Districts and the general public. The ultimate utility of the resulting products will be influenced by the effectiveness of the technology transfer process. Five basic forms of technology output are proposed, including:

a. Computerized wetlands values assessment technique. The assessment technique will be provided to CE Districts on software for use with microcomputers. A user's guide will also be provided.

b. Computerized wetlands values database. This database, which is currently available to several CE districts, will allow rapid retrieval of values information useful in applying the assessment technique.

c. Technical reports. Technical reports of all CE wetlands values studies will be made available to CE Districts.

d. Information brochures. A series of color brochures that describe wetlands functions and values in lay terms will be produced for distribution to the general public.

e. Training course. A proponent-sponsored training course will be developed to include instruction on use of the assessment technique and values database.

PART VII: FRAMEWORK FOR PROJECT IMPLEMENTATION

142. This part of the study plan describes all project activities for purposes of fiscal organization. All completed, ongoing, and proposed project activities are presented (Table 22). The project has been divided into seven major topics and 37 secondary topics. The general objective and an approximate schedule for implementation of each topic are also presented. Most topics in Table 22 are necessarily broad at this time and should not be interpreted as task-level items. Development of specific tasks will be accomplished prior to implementation of individual secondary topics.

Table 22

Wetlands Values Research Framework

Research Topics	Objectives	Schedule-Fiscal Year Pre-84	84	85	86	87	88	89
I. Development of Wetlands Values Study Plan	Present a logical framework for developing a wetlands assessment technique.							
A. Examination of Existing Wetlands Assessment Techniques	Review existing wetlands evaluation methods and determine the advantages and disadvantages of each method.	X						
B. Survey of CE Wetlands Values Information Needs	Identify wetlands evaluation techniques used by CE Districts, assess national applicability, and determine what wetlands values information is needed by CE personnel.	X						
C. Literature Review of Wetlands: 1. Hydrologic Functions 2. Water Quality Functions 3. Fish and Wildlife Habitat Functions 4. Socioeconomic Functions	Determine, on a regional basis, what wetlands values information is available, where data gaps exist, and what research is needed to address data gaps. Four reviews have been conducted.	X	X					
D. CE Wetlands Values Workshop	Review a Preliminary Wetlands Values Study Plan and provide recommendations for revising, establishing research priorities, and identifying needs for wetlands values information.		X					
II. Assessment Technique Development	Develop a technique that evaluates all known wetlands functions and meets CE regulatory and environmental planning needs.							
A. National Wetlands Values Assessment Workshop	Critically review the Federal Highway Administration (FHWA) wetlands assessment technique (Adamus 1983) and recommend revisions and research to improve the technique.	X						
B. Revise and Update the FHWA Wetlands Assessment Technique Using Recent Technical Literature	Ensure the technical validity of the FHWA Technique within constraints imposed by the current literature database.		X	X				
C. Computerize the FHWA Technique	Develop a user-friendly computer program for use on microcomputers to simplify procedural and analytical steps in the method.			X	X	X	X	X
D. Develop Sensitivity Analysis	Develop and incorporate a mechanism into the FHWA Technique to reflect some level of confidence in derived conclusions.				X	X	X	
E. Regionalize the FHWA Technique	Develop procedures to reflect regional differences in wetland types and public priorities.				X	X	X	X

(Continued)

Table 22 (Continued)

Research Topics	Objectives	Schedule-Fiscal Year Pre-84	84	85	86	87	88	89
F. Field Test the FHWA Technique	Evaluate and refine the computer program and assess field implementation of the technique.			X	X	X	X	
G. Incorporate Research Results Obtained in Studies III-VI	Revise the assessment technique to reflect newly acquired data from research results.			X	X	X	X	X
III. Long-Term Holistic Studies	Assess the ability of priority wetland types to perform many wetlands functions, quantify the degree to which the wetland type performs each function, and identify diagnostic characteristics for each function.							
A. Assess Wetlands Functions of Bottomland Hardwoods in the Interior: Midcentral and Gulf and South Atlantic Coasts Regions	Determine indicators which reflect the opportunity and effectiveness of bottomland hardwood wetlands to provide hydrology, water quality, and fish and wildlife habitat functions in those regions.			X	X	X	X	
B. Assess Wetlands Functions of Freshwater Marshes in the Interior: North Central-Great Lakes Region	Determine indicators which reflect the opportunity and effectiveness of freshwater marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
C. Assess Wetlands Functions of Estuarine Marshes in the Pacific Coast Region	Determine indicators which reflect the opportunity and effectiveness of estuarine marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
D. Assess Wetlands Functions of Swamps in the North Atlantic Region	Determine indicators which reflect the opportunity and effectiveness of swamps to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
E. Assess Wetlands Functions of Tundra in the Alaska Region	Determine indicators which reflect the opportunity and effectiveness of tundra to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
F. Assess Wetlands Functions of Freshwater Marshes in the Pacific Coast Region	Determine indicators which reflect the opportunity and effectiveness of freshwater marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
G. Assess Wetlands Functions of Freshwater Marshes in the Gulf and South Atlantic Coasts Region	Determine indicators which reflect the opportunity and effectiveness of freshwater marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	

(Continued)

Table 22 (Continued)

Research Topics	Objectives	Schedule-Fiscal Year Pre-84	84	85	86	87	88	89
H. Assess Wetlands Functions of Freshwater Marshes in the North Atlantic Region	Determine indicators which reflect the opportunity and effectiveness of freshwater marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
I. Assess Wetlands Functions of Freshwater Marshes in the Interior: Desert Steppe Region	Determine indicators which reflect the opportunity and effectiveness of freshwater marshes to provide hydrology, water quality, and fish and wildlife habitat functions in this region.			X	X	X	X	
IV. Function-Specific Studies	Assess the ability of particular wetland types to perform selected wetlands functions, quantify the degree to which the wetland type performs each particular function examined, and identify diagnostic characteristics for each function.							
A. Assess Selected Wetlands Functions of Pocosins in the Gulf and South Atlantic Coasts Region	Determine indicators which reflect the opportunity and effectiveness of pocosins to provide hydrology and water quality functions in this region.				X	X		
B. Assess Selected Wetlands Functions of Riparian Wetlands in the Interior: Desert Steppe Region	Determine indicators which reflect the opportunity and effectiveness of riparian wetlands to provide wintering habitat for big game species in this region.				X	X		
C. Assess Selected Wetlands Functions of Freshwater Tidal Marshes and Swamps in the Gulf and South Atlantic Coasts and North Atlantic Regions	Determine indicators which reflect the opportunity and effectiveness of freshwater tidal marshes and swamps to provide spawning and nursery habitat for aquatic biota in these regions.				X	X		
D. Assess Selected Wetlands Functions of Prairie Potholes in the Interior: North Central-Great Lakes Region	Determine indicators which reflect the opportunity and effectiveness of prairie potholes to provide hydrology and water quality functions in this region.				X	X		
E. Assess Selected Wetlands Functions of Bogs in Alaska	Determine indicators which reflect the opportunity and effectiveness of bogs to provide habitat for migratory waterfowl in this region.				X	X		
F. Assess Selected Wetlands Functions of Estuarine Marshes in Alaska	Determine indicators which reflect the opportunity and effectiveness of estuarine marshes to provide food chain production and spawning and nursery habitat for aquatic biota in this region.				X	X		

(Continued)

Table 22 (Continued)

Research Topics	Objectives	Schedule-Fiscal Year Pre-84	84	85	86	87	88	89
G. Assess Selected Wetlands Functions of Riparian Forests in the Pacific Coast Region	Determine indicators which reflect the opportunity and effectiveness of riparian forests to provide flood storage and desynchronization and sediment retention functions in this region.				X	X		
H. Assess Selected Wetlands Functions of Estuarine Marshes in the Gulf and South Atlantic Coasts Region	Determine indicators which reflect the opportunity and effectiveness of estuarine marshes to provide shoreline anchoring and erosion abatement functions in this region.				X	X		
V. Special Studies	Address particular research needs not covered under holistic or function-specific studies.							
A. Synthesis Reports on: 1. Hydrologic functions of bottomland hardwoods in the Interior: Mid-central Region 2. Water quality functions of estuarine marshes in the North Atlantic Region 3. Ground-water recharge and discharge functions of swamps in the North Atlantic Region	Conduct detailed analyses of literature on selected functions in particular regions and wetland types, and present in a form useful to CE Districts.			X	X			
B. Analysis of Altered Wetlands in the Pacific Coast Region	Determine the ability of diked wetlands to perform various wetlands functions.					X		
C. Ecological Modeling	Provide predictive capabilities for assessing response of wetlands functions to hypothetical perturbations.				X	X	X	
D. Laboratory Studies	Assess, under controlled conditions, the validity of particular diagnostic characteristics identified in the long-term holistic studies.			X	X	X	X	
VI. Socioeconomic Studies	Develop techniques for monetary assessment of wetlands functions.				X	X	X	X
VII. Technology Transfer	Develop effective methods for transferring developed information and assessment techniques to CE field elements and receive recommended revisions from CE field elements.							
A. Computerized Wetlands Values Assessment Technique	Provide software for implementing the wetlands assessment technique on microcomputers.		X	X	X	X	X	X
B. Computerized Wetlands Values Database	Provide a mechanism for rapid retrieval of wetlands values literature.		X	X	X	X	X	X

(Continued)

Table 22 (Concluded)

Research Topics	Objectives	Schedule-Fiscal Year Pre-84	84	85	86	87	88	89
C. Technical Reports	Disseminate research results	X	X	X	X	X	X	X
D. Information Brochures	Prepare brief color brochures to inform the general public about wetlands values.			X	X	X	X	X
E. Training Courses	Provide instruction on wetland values and implementation of evaluation techniques.			X	X	X	X	X

PART VIII: CONCLUSIONS

143. National priority CE wetlands functions and values research needs have been identified following a systematic approach. These priority research needs were purposely established on a technical basis, without considering such administrative constraints as fiscal and manpower resource limitations. These constraints are realities, and it is unlikely that the CE will be able to complete all high-priority research within a reasonable time frame. Consequently, the WES is actively coordinating research efforts with other Federal agencies who have an interest in and a need for information resulting from wetlands functions and values research. Such efforts can result in the wisest use of available resources in accomplishing the greatest possible portion of the research needs identified in this study plan. An interagency steering committee has been established to coordinate research activities, which should accelerate development of a useful wetlands evaluation technique.

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